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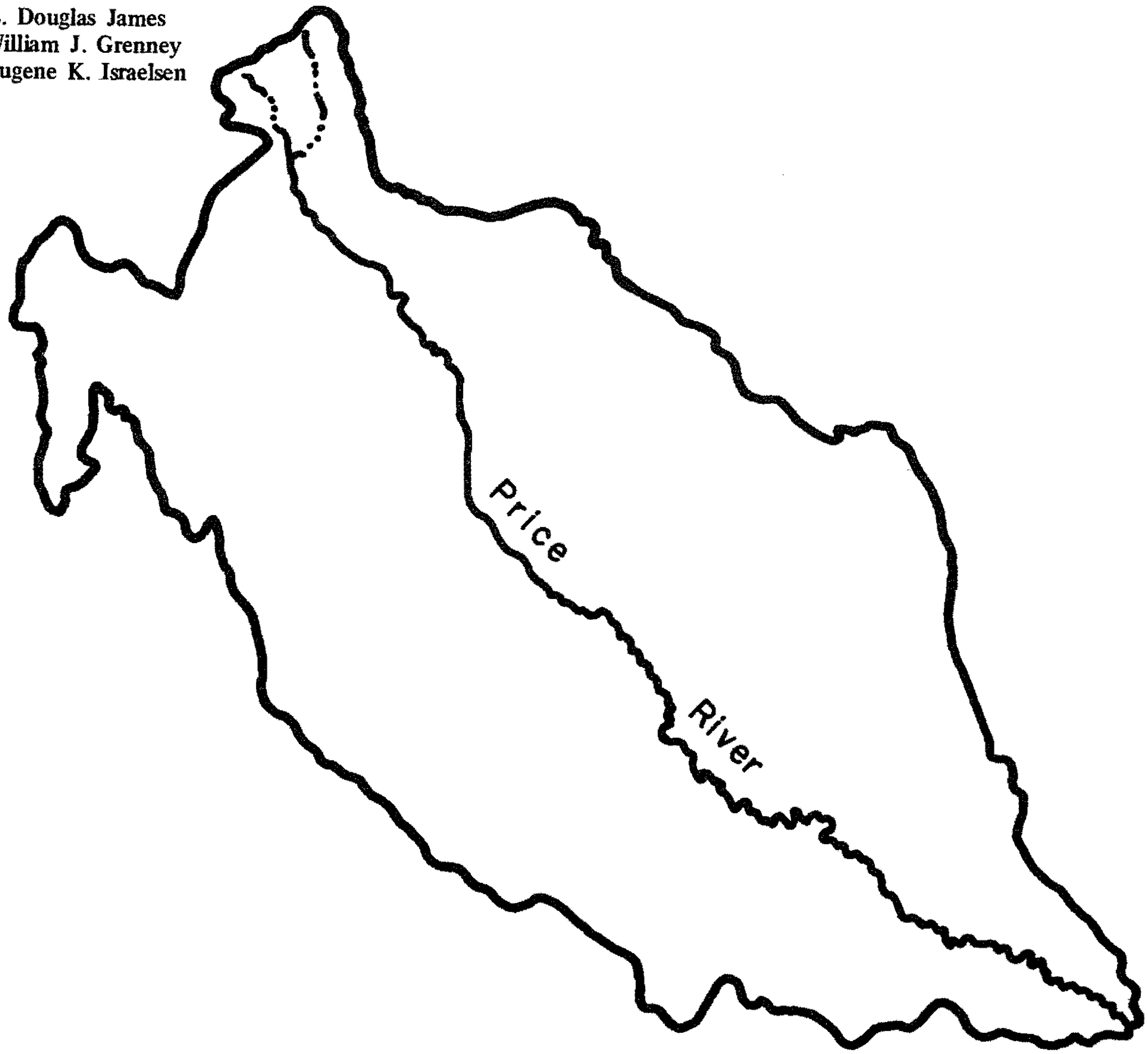

Utah Water Research Laboratory
Utah State University
Logan, Utah 84322

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WATER RESOURCES PLANNING SERIES
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SALT UPTAKE IN NATURAL CHANNELS TRAVERSING MANCOS SHALES IN THE PRICE RIVER BASIN, UTAH

by

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ABSTRACT

Field and laboratory measurements of process rates for runoff and salt movement were used to develop and calibrate a hydrosalinity model of outflows from the Price River Basin at Woodside, Utah. The field measurements were specifically used to formulate a model for estimating surface flow (both overland and from small ephemeral channels) in the Coal Creek Basin on the valley floor of the Price River Basin. The basin simulation assessment model (BSAM) was used to combine local flows and model total outflow from the Price River.

The results must be regarded as a first generation model that, while giving ostensibly reasonable results, needs much additional refinement and validation by collecting additional field data. As to field data, observed salt loading rates reached 518 pounds per square mile daily, groundwater inflow declined steadily throughout the summer but maintained constant salt concentrations, channel efflorescence varied more than 100 fold with the largest concentrations occurring in saturated bed material, and turbulent mixing and cyclic drying added to salt dissolution rates.

Extrapolation of the results with the Coal Creek model showed only a very small percentage of the salt loading from the valley floor to originate from natural lands. BSAM showed average annual salt leaving the Basin at Woodside to be 190,000 tons, 114,000 coming from the mountain area and 76,000 from the valley floor. Of the valley floor contribution, only 3,500 tons are produced by surface runoff from nonirrigated areas.

Topics to be emphasized in further model development include salt contribution from percolation snowmelt on natural lands, groundwater movement, the formation and dissolution of efflorescence, and salt-sediment transport by the sharp hydrographs on small ephemeral streams.

ACKNOWLEDGMENTS

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CHAPTER I

INTRODUCTION

The Problem

Salinity is a major issue in the Lower Colorado River Basin. A criterion for flow-weighted average annual salinity concentration of 879 mg/l was established in 1976 as a maximum for flows at Imperial Dam. Three years before, the seven basin states had formed a Colorado River Basin Salinity Control Forum to coordinate salinity control efforts. A provision, known as Minute 242, in an agreement with Mexico, assured that waters delivered to the Mexican diversion point would have an annual average salinity of no more than 115 ppm over that of water arriving at Imperial Dam. While average annual salinities have decreased from 890 mg/l in 1970 to a little below 800 mg/l in 1981, a decline probably associated with the filling of Lake Powell, the expectation for the long run is for increasing salinity levels unless an effective control program is established. Any major future increases in salinity would only add to already major losses to agriculture and damages to municipal and industrial water users (U. S. Department of the Interior 1974 and Andersen and Kleinman 1978).

Multiple methods are being explored to hold down salinity concentrations. Two principal alternatives exist. One is to remove salt from the water through construction of a desalting complex as has been authorized by PL 93-320 for the United States to fulfill its obligation with Mexico. A potentially less expensive alternative is to reduce the concentration of salt reaching the mouth of the Colorado. The concentration may be reduced either by adding to the water or by reducing the salt. The high economic value of water in the Lower Basin makes using more to transport salt unattractive and focuses attention on ways to reduce the salt content.

One approach to reducing salt content is to reduce the amount of salt leaving the Upper Basin either by augmenting natural salt precipitation processes or by finding an economically attractive use for salt brine. Explored options include salt precipitation in reservoirs (Messer et al. 1981), export of salt brines as the conveying fluid in coal slurry pipelines (Israelsen, et al. 1980), and use of the salt for electric power production in salt-gradient solar ponds (Riley and Batty 1982). All three have cost or technical feasibility problems.

Alternatives for reducing the original salt loading entering the river system are even more difficult to evaluate because the salt sources are so many and so diffuse. Salts enter the Colorado River after being leached from irrigated soils, concentrated by evapotranspiration, and returned as agricultural drainage. Municipal and industrial uses add salts from extracted groundwater, expose salt bearing materials to weathering, and increase leaching as a result of outside water uses in residential areas. Fossil fuel extraction and processing in the Upper Basin are being particularly watched as future threats.

All of these man-caused sources of salt loading add to the larger natural salt loading. Mineral springs and natural groundwater seeping from marine formations abound. Natural diffuse sources are scattered over vast areas of open land.

Blackman et al. (1973) estimate that 37 percent of the total salt loading to the Colorado River occurs from diffuse sources in the Upper Basin. Mountainous areas yield most of the river flow from a relatively small fraction of the catchment and supply relatively high quality water. As the streams traverse the immense, semiarid lowlands, little flow is added and water quality deteriorates as water is used consumptively and the streams interact with natural salt bearing geological formations.

The Price River subbasin of Central Utah (Figure 1.1) is a miniature of this salt loading pattern. Relatively high quality flow (less than 1000 mg/l TDS or total dissolved solids) originates in mountainous headwater areas. After emerging from the mountains, the river traverses an irrigated area amounting to about 2 percent of the total catchment. Further downstream, it crosses large areas of natural and range lands. It contacts a marine formation high in soluble salt content called the Mancos Shale. Finally, it reaches Woodside with an average dissolved solids concentration of about 2500 mg/l.

This most downstream river section, where the Price River flows through arid range lands having an average annual precipitation of only about 8 inches, provides a setting to study and quantify natural salt loading. Hopefully, the relationships derived and the understanding gained from their quantification can be used to assess salinity control management alternatives applicable throughout the entire Upper Colorado Basin.

Study Objectives

The objectives of this investigation of the natural processes which contribute salt to the Price River were:

1. Locate stream reaches receiving diffuse natural salt loadings.

2. Identify the major processes and mechanisms within those processes causing salt loading within the selected channels.

3. Propose and test mathematical relationships for quantifying salt picked up by overland and channel flows and entering these channels.

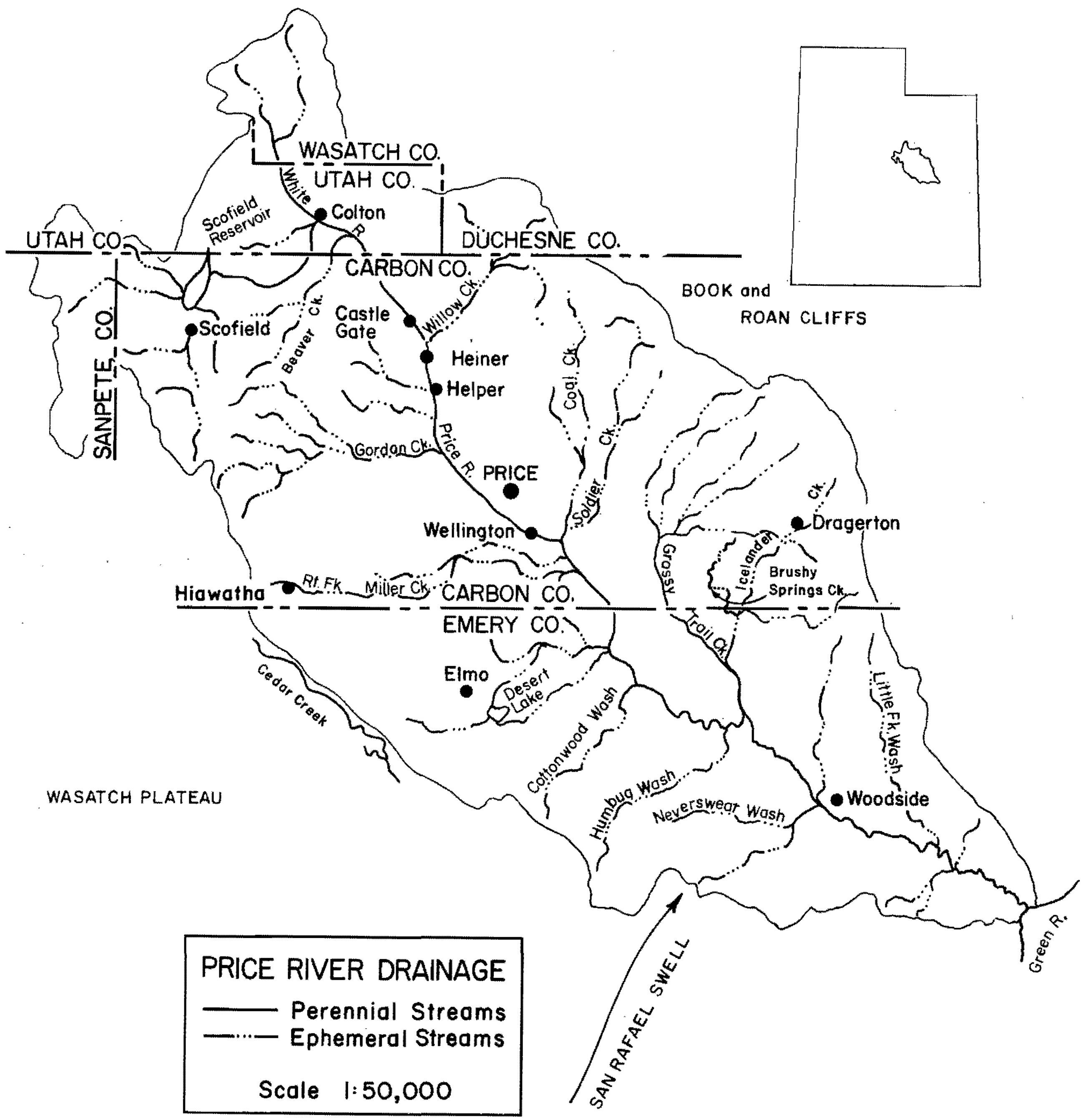


Figure 1.1. Price River Basin (taken from Riley et al. 1977).

4. Integrate the selected relationships into a mathematical model of the natural processes loading the stream with salts.

5. Employ the hydrosalinity model in analysis of the contribution of salt loadings from natural areas in the Price River Basin.

Significance of the Study

A well founded understanding of salt loading processes is required to develop effective salinity management programs for the arid Colorado River Basin. The understanding needs to identify and describe the physical processes picking salt up from diffuse sources and carrying it downstream, establish quantitative relationships for estimating salt loading and transport, and thereby provide a basis for selecting promising land and water management programs and predicting how well they will perform. The effort to build that understanding has been severely handicapped by the paucity of data on salt movement. Hence, this study seeks both to collect data and to model, to do both simultaneously in an interactive way with the hope of advancing more quickly to the needed understanding.

According to Hyatt et al. (1970), "Research is needed to improve relationships for predicting water quality as a function of parameters such as various watershed characteristics and hydrology. Because of the complex processes which occur in a watershed, it is likely these relationships will need to be empirical in nature. As improved relationships are developed, they can be incorporated into system models." This project developed a first generation mathematical model capable of simulating the major salinity uptake mechanisms from an ephemeral catchment in the Mancos Shale wildlands. Such simulation begins quantitative definition of relationships between catchment characteristics and salt loading in a rigorous way that can later be used in examining ways a salinity control program can reduce salt loading. Without the discipline of a verified model for their assessment, management proposals are only guesses.

Literature Review

Streamflow and salinity functions

In one of the first formal studies of salt movement in semiarid western streams, Hem (1948) found that total dissolved solids (TDS) varied with flow in an inverse manner. Seasonal and diurnal variations were both found. A typical salt concentration versus stream flow relationship is shown in Figure 1.2 for the Gila River at Bylas, Arizona, for six storm events. Hem (1948) hypothesized that rising conductivity curves are due to dissolution of salts left in the channel by precipitation and evaporation; and that falling conductivity curves are the result of dilution.

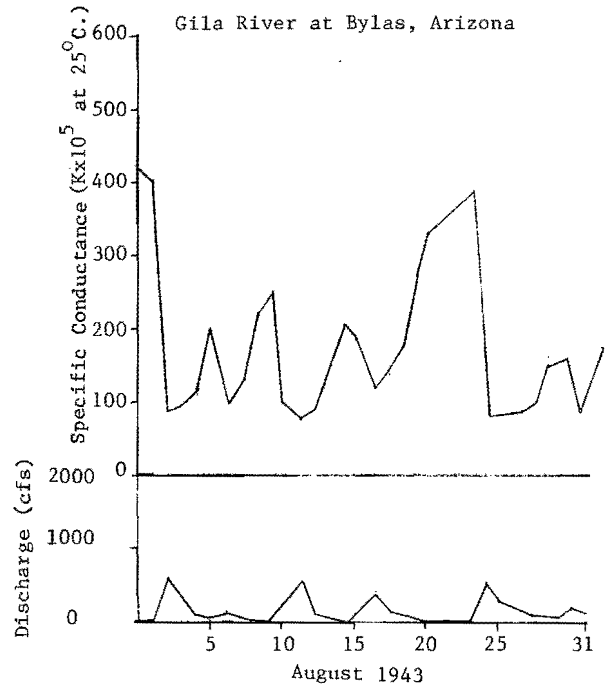


Figure 1.2. Daily conductance and the mean daily discharge measurements for the Gila River at Bylas, Arizona, during August 1943 (taken from Hem 1948).

Durum (1953) studied the salt-discharge relationships for the Saline River, Kansas. He observed the average chloride concentration to be directly proportional to the TDS and proposed the following relationship for relating mean chloride concentration to mean flow:

$$C_c = k/Q \qquad (1.1)$$

in which

C_c = Chloride concentration in mg/l
Q = Water flow rate in cfs
k = Constant

In testing his equation with empirical data, Durum (1953) had a correlation coefficient of 0.94. The chloride concentration was found to be high and highly variable at low water flow rates and low at high flows (Figure 1.3). During periods of rapidly rising stages, however, the chloride concentration was observed to increase. The author attributed this anomaly to the dissolution of soluable materials deposited in the channel bed as water evaporates during low flows and then scoured out and carried as suspended or bed load with the rising flow. He estimated the contribution of salt from groundwater by assuming that flow during the winter months equals the groundwater inflow.

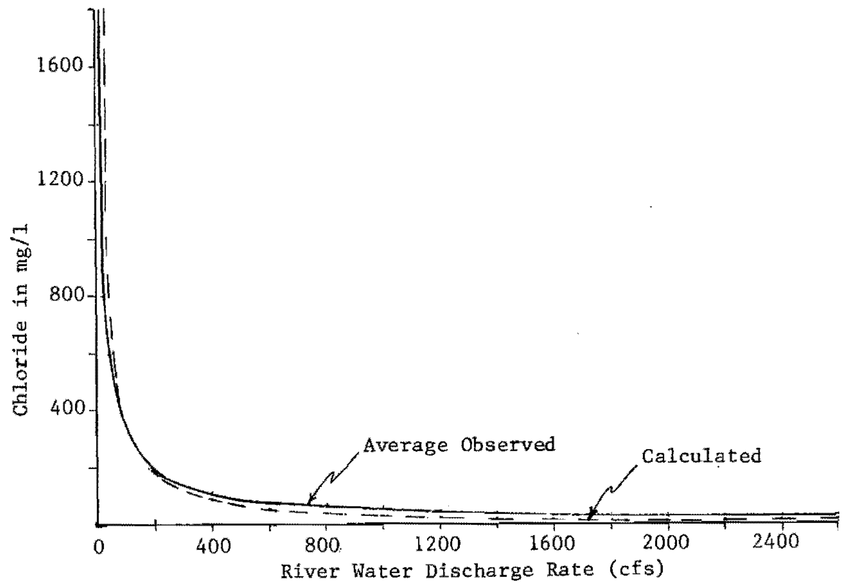


Figure 1.3. Relation of chloride concentration to water discharge rate for the Saline River, Kansas (taken from Durum 1953).

Ward (1958) developed the following regression expression for the Arkansas River, Oklahoma, and the Red River, Texas:

$$\log C_i = a + b \log Q + c (\log Q)^2 \quad . \; . \quad (1.2)$$

in which

a, b, c = Constants
C_i = Specific ion concentration in mg/l

He tried other ions besides chlorides, observed high variability in his data, and achieved a low correlation coefficient.

Ledbetter and Gloyna (1964) proposed three empirical equations for predicting the salt load in southeastern streams. The authors utilized an exponential loading equation as the base function:

$$C = kQ^b \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1.3)$$

in which

k and b = Constants
C = Salt concentration in mg/l

Their second equation converted b to a variable exponent:

$$b = pQ^n \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1.4)$$

in which

p and n = Constants

Their third equation used a different function for the variable exponent, namely:

$$b = f + g \log /A_q + h\, Q^n \quad . \; . \; . \; . \quad (1.5)$$

in which

f, g, h, n = Constants
A_q = An antecedent flow index defined as:

$$A_{q_k} = \sum_{i=1}^{30} Q_i/i \quad . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \; . \quad (1.6)$$

in which

A_{q_k} = The antecedent flow index on the day of the event (day k)
Q_i = Water flow rate in the stream on day i in cfs
i = The number of days back from the kth day

Hart et al. (1964) observed that applying Ledbetter and Gloyna's (1964) equations requires excessive data and proposed, from work done on the Russian River in California, the function:

$$C = a_1\, Q_g^{\;b_1} + a_2\, Q_i^{\;b_2} + a_3\, Q_s^{\;b_3} \quad . \; . \quad (1.7)$$

in which

Q_g = Groundwater flow rate in the river in cfs

Q_i = Interflow flow rate in the river in cfs

Q_s = Surface flow rate in the river in cfs

a and b = Constants determined by a regression based on field observations

In this relationship, salt loading is divided among three flow paths and varies exponentially with respect to flow.

Langbein and Dawdy (1964) suggested that watershed chemical weathering can be described according to Nernst's law and proposed the functions:

$$dL/dt = DA \frac{(C_s - C)}{C_s} \quad \ldots\ldots\ldots \quad (1.8)$$

in which

L = Dissolved mass
t = Time
D = Maximum rate of dissolution
C_s = Saturation concentration
A = Drainage area under consideration

By simple mass balance differencing, Equation 1.8 may be represented as:

$$Q(C_o - C_i) = DA \frac{(C_s - C)}{C_s} \quad \ldots\ldots\ldots \quad (1.9)$$

in which

C_i = Concentration of influent water (water in the river channel entering the area drained by the subbasin of area, A)

C_o = Concentration of effluent water (water leaving the subbasin of area, A)

Algebraic manipulation of Equation 1.9 yields:

$$C_o = \frac{C_s\ (1 + C_i\ Q/DA)}{1 + QC_s/DA} \quad \ldots\ldots\ldots \quad (1.10)$$

Equations 1.8 to 1.10 are nearly the same as those proposed by Jurinak et al. (1977) 13 years later.

From studying the total salt load per square mile in various large watersheds, Langbein and Dawdy (1964) observed that on a log-log plot the annual salt load increases linearly with annual runoff up to approximately 3 inches (Figure 1.4). Thereafter, loads begin to decline.

Hendrickson and Krieger (1964) and Toler (1965) in separate studies of Southeastern U.S. streams described a hysteresis effect in the pattern of salt concentration during storm events. Depending upon whether the stage is rising or falling, different concentrations were observed for a given water flow rate. The authors attribute the hysteresis effect to time variation in the salt dissolution process, changes in the rate of surface runoff, and the inflow of relatively constant quality groundwater. Toler (1965) observed that the hysteresis can be clockwise or counter-clockwise depending upon the variability of the quantity of groundwater inflow.

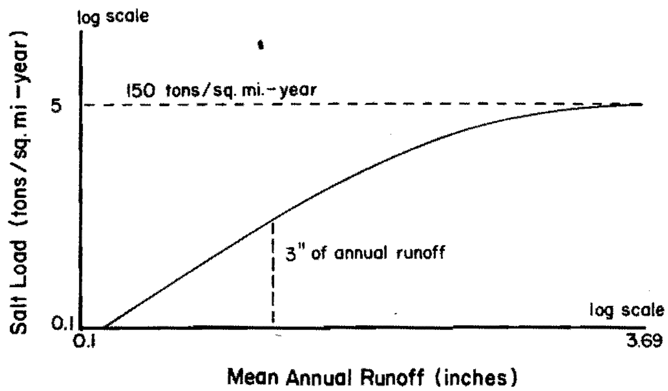


Figure 1.4. Salt load versus annual surface runoff (taken from Langbein and Dawdy 1964).

From a study of the Hubbard Brook Experimental Forest, New Hampshire, Johnson et al. (1969) proposed the following model for stream water chemistry based upon mixing and mass balance:

$$C = \frac{C_s}{1 + \beta\ Q} + C_\alpha \quad \ldots\ldots\ldots\ldots \quad (1.11)$$

in which

β = Constant

C_α = Rainwater concentration

C_s = Groundwater concentration minus rainwater concentration

Salinity concentrations predicted by the model were consistently higher than those observed in the prototype system.

Gibbs (1970) identified three major mechanisms contributing salt loadings to rivers: 1) atmospheric precipitation, 2) mineral dissolution, and 3) evaporation-crystallization. Rivers vary greatly in how salinity sources divide between precipitation and rocks as illustrated in Table 1.1.

Pionke and Nicks (1970) applied salinity/flow models to ephemeral streams in Oklahoma. Flow and salinity, as functions of time for two typical storms on the West

Table 1.1. Salinity sources (taken from Gibbs 1970).

Salinity Sources	Contribution from Precipitation (percent)	Contribution from Rocks (percent)
Rio Tefe (rain-dominated river type)	81	19
Ucayali (rock-dominated river type)	4.8	95.2
Rio Grande (evaporation-crystallization river type)	0.1	99.9

Bitter Creek Waterhsed, are shown by Figure 1.5. The authors obtained a correlation coefficient (r^2) of 0.53 when applying the common exponential function, Equation 1.3, to the runoff events. By utilizing monthly average values and multivariate regression a correlation coefficient (r^2) of 0.8 was achieved.

Hall (1970 and 1971) derived six models relating TDS to streamflow based upon the equations:

$$\frac{dL}{dt} = C\,\frac{dV}{dt} + V\,\frac{dC}{dt} \quad \dots\dots\dots\dots \quad (1.12)$$

$$\frac{dV}{dt} = Q - I \quad \dots\dots\dots\dots\dots \quad (1.13)$$

$$V = aQ^b \quad \dots\dots\dots\dots\dots\dots \quad (1.14)$$

in which

L = Total load
V = Volume
t = Time
I = Inflow
a and b = Constants

His models describe steady-state systems and do not account for hysteresis effects accompanying rising and falling stages. The equations are empirical, and the constants are best estimated by statistical fit.

Lane (1975) described salt contributions for surface flows as originating primarily from dissolution of efflorescence and mechanical weathering. Thus, the resultant concentration might be described as a function of both current and antecedent flows. That is, if antecedent flows have been high, then few salts would exist on the soil surface. If the antecedent flows have been low, then the availability of surface salts probably would be high. He proposed the general relationship illustrated by Figure 1.6.

Salinity models

Several deterministic and parametric watershed salinity models have been developed at Utah State University. Hyatt et al.

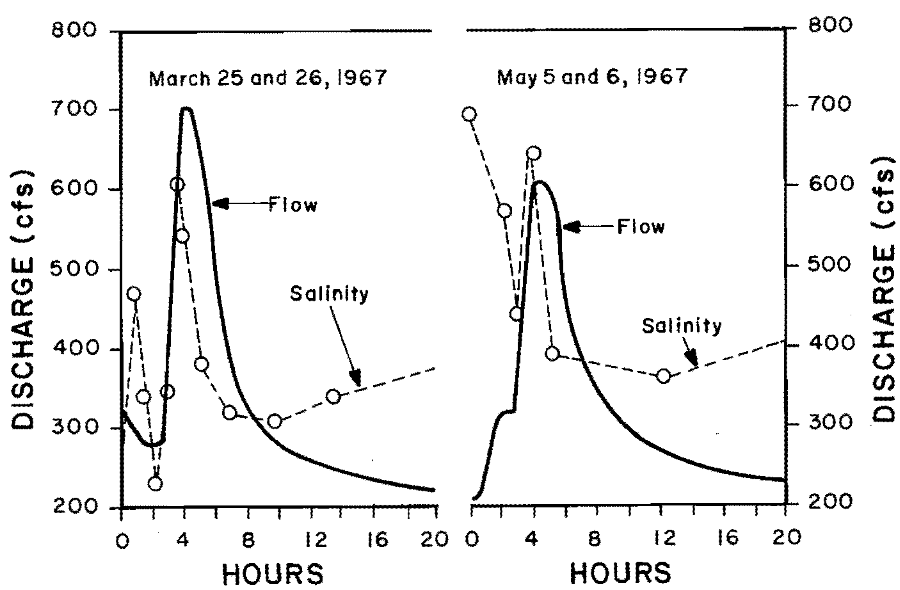


Figure 1.5. Flow (cfs) and salinity (ppm) for typical storms on the West Bitter Creek watershed, Oklahoma (taken from Pionke and Nicks 1970).

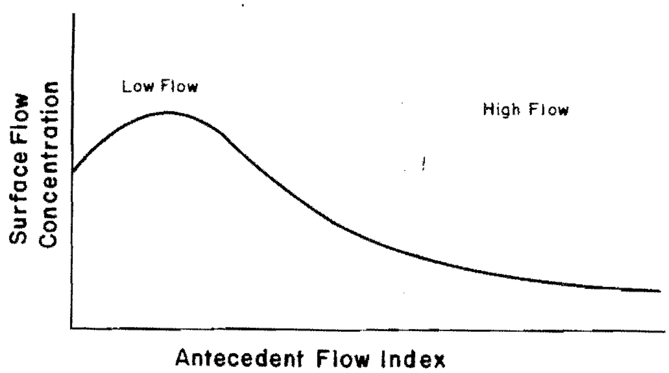


Figure 1.6. Hypothetical antecedent flow index (taken from Lane 1975).

(1970) modeled average monthly salinity mass flow on a major subbasin of the Upper Colorado River. A distributed parameter hydrologic watershed model was coupled with a salinity uptake model. Flow separation was utilized in the hydrologic model, and separate salt loads were associated with surface flow, groundwater flow, and interflow. Salt concentrations in groundwater and interflow were assumed constant. The surface inflow concentrations for ungaged sources were related to water flow rates by utilizing exponential regression equations. To incorporate flash flows from small watersheds, the average monthly salt concentrations were increased. It was assumed initially that salt load increases within the valley bottoms could be attributed entirely to agriculture. However, on the basis of this assumption, the initial simulated salinity concentrations associated with subbasin outflows were low by factors ranging from two to ten. To add to the salt loading, a channel salt uptake mechanism was assumed according to the following hypothesis:

> ...Much of the water which enters the alluvium as influent flow in the upstream portion of the basin returns again to the stream channel in the lower reaches, and that within a particular subbasin the rate of interchange between surface water and groundwater may be influenced by water levels in the stream channels. Hence, during periods of high streamflow some increase in the interchange rate might be expected (Hyatt 1970, p. 34).

The following two empirical equations were used to account for this loading:

$$K_p = n\ (Q_r)^m \quad . \ . \ . \ . \ . \ . \ . \ . \ . \quad (1.15)$$

in which

K_p = Percentage of surface flow interchanged or recirculated through the stream alluvium or groundwater
Q_r = Monthly surface flow rate in cfs
m = Slope of the line of K_p plotted against Q_r on log-log paper
n = Intercept on the K_p-axis of the log-log plot

and

$$S_r^{NS} = K_p\ Q_r\ C_g \quad . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \ . \quad (1.16)$$

in which

S_r^{NS} = Rate of salt flow contributed from natural sources within the basin
C_g = Average water salinity level within the groundwater basin or stream alluvium. This quantity, assumed to be constant throughout the simulation period, is estimated from either well samples or the average salinity level of the base flows of the streams within the subbasin.

The water and salt budgets Hyatt derived by applying this model to the Price River Basin are tabulated in Table 1.2. These figures suggest that irrigation is a relatively minor salt contributor to the waters of the Price River. The report concluded that "... more research is needed to delineate between natural and man induced salt loading before stringent and perhaps unnecessary controls are placed on human activities" (Hyatt 1970, p. 97).

Thomas et al. (1971) proposed a hydrologic-salinity model that can be applied to both irrigated and nonirrigated areas and utilized thermodynamic ionic relationships for estimating salt uptake concentrations. The model was successfully applied to the Bear River, Utah, and simulated Ca, Mg, Na, SO_4, Cl, and HCO_3. The model, however, is unwieldy due to its extensive data requirements.

Hill (1973) applied a hydrologic-salinity model to the Little Bear River, Utah. Natural weathering was not considered, and salt uptake was assumed to be limited to agricultural and groundwater sources. Flow separation and average monthly salt loading factors were used.

Narasimhan (1975) added a biochemical nitrogen subroutine for agricultural percolated waters to the Thomas et al. (1971) model. The expanded model was successfully applied to the Twin Falls tract of the Snake River Basin in Idaho. However, the amount and complexity of the required data are also a problem in applying this model.

Table 1.2. Water budget for the valley floor area of the Price River Basin (adapted from Hyatt et al. 1970).

	Water (AF/yr)		Salt (Tons/yr)	
	Inflows	Outflows	Inflows	Outflows
Measured Surface	70,000	68,000	20,000	220,000
Unmeasured Surface	28,000		45,000	
Precipitation	15,000			
Natural Loading			168,000	
Agricultural Loading			15,000	
Subsurface		4,000		28,000
Phreatophyte Consumptive Use		5,000		
Evapotranspiration from Soil		36,000		
TOTAL	113,000	113,000	248,000	248,000

Willardson et al. (1979) published a chemical model of soil-irrigation water cation exchange. An application to the Ashley Valley of Utah examined the sensitivity of streamflows and salinity to irrigation water management alternatives and found the salinity of the streamflow to be most sensitive to increases in water conveyance efficiency (canal lining). The effect of the lining, however, would depend on how the water saved was used.

Peterson et al. (1980) used experiments on the rate of salt release from Mancos Shale derived soils to calibrate a chemical equilibrium model, derived from ion association theory, in interface with a kinetic model of salt release. The model was able to predict rates of salt release from suspended sediment.

Narasimhan et al. (1980) reviewed development of the hydrosalinity modeling art in terms of usefulness for water management decision making. They examined the assumptions, approaches, data requirements, and applications for 17 existing models. Eight models portrayed water and salt movement down a stream or through a river basin by using steady-state relationships, treating salinity as a single conservative constituent (TDS), and using long time increments (generally months). Two models treat individual ions in the soil-water system, and four more integrate soil-water chemistry with solute transport. Finally, three models also reflect groundwater chemical reactions within the water or between the water and the aquifer.

Hydrosalinity of the Price River Basin

The Price River flows average (1931-1960) 239,000 tons of salt and 71,800 acre-feet of water. According to Jeppson et al. (1968), the Price River contributes only 0.66 percent of the flow to the Colorado River at Lee Ferry while its salt contribution is 2.79 percent of the total. No other major tributary of the Upper Colorado River has such a high salt to water ratio (about 2450 mg/l).

Furthermore, Mundorff (1972) has noted that there are few identifiable point sources adding salinity to the Price River flow. Rather, the salt sources appear to be widely diffused over the basin and affect all major Price River tributaries. During average or low flow periods, salinity concentrations are high in all of them.

On natural lands, weathering processes and various human activities expose soluble minerals at the ground surface. Rainfall causes runoff that dissolves some of these salts and erodes sediments that carry more. In addition the churning action grinds the sediments as overland flow collects in ephemeral channels, exposing more soluble minerals. Additional water infiltrates to interact with the soil in depositing and dissolving salts before emerging as interflow or groundwater discharge.

Salts from all these sources (as well as from irrigated lands) concentrate in the channels. Iorns et al. (1965) indicated that the flow in the Price River alternately moves from the stream into the alluvium and back again. The interchange between water and alluvium deposits salts in the bed during low flow periods and contributes to the deterioration of water quality during high flows. In addition during high flows, additional salts enter the flow as channel banks erode and collapse into the stream. These banks may be particularly high in salt content where salts have been left behind by evaporation from seepage during low flow periods.

During the growing season, the Price River is almost entirely diverted for irrigation of about 20,000 acres or about 8 percent of the valley area (see Figure 1.7). The principal canals serving the area are the Price-Wellington, Carbon, and the McFadden branch of the Cleveland Canal. Water in the latter is imported from Huntington Creek in the San Rafael River Basin. Estimates of the

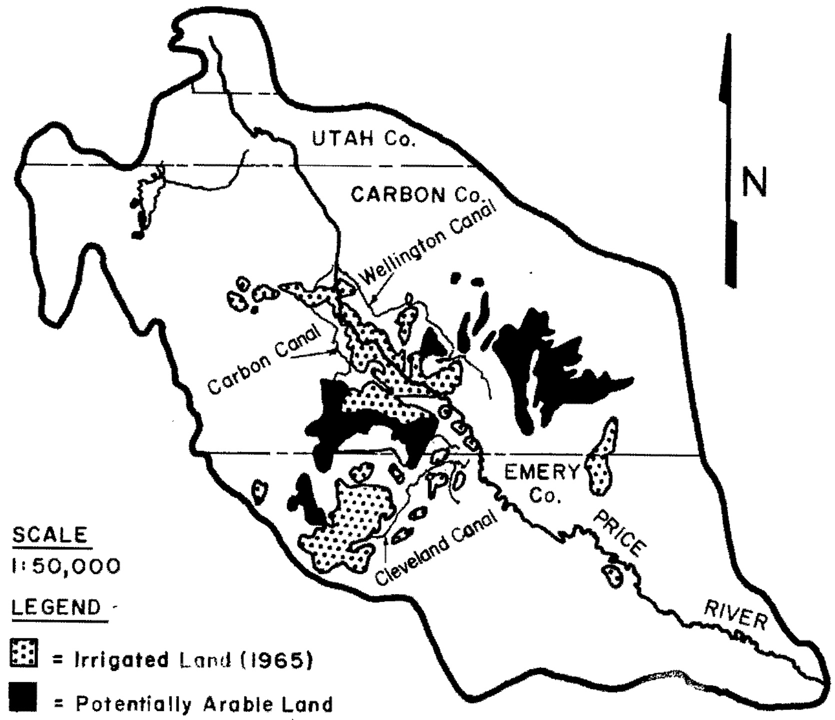


Figure 1.7. Irrigated and potentially arable land in the Price River Basin (Utah Division of Water Resources 1975).

salt contribution from irrigation range from about 6 percent, or 15,000 tons per year, by Hyatt et al. (1970) to about 33 percent, or 80,000 tons per year by Gifford et al. (1975).

Ponce (1975) conducted an intensive field investigation of salt pickup by overland flows crossing Mancos Shale wildlands. Overland runoff was generated at several geologic locations in attempts to quantify salt movement, erosion, and loading rates. Spatial heterogeneity, however, was so extreme that the results are inconclusive. His best hypothesis was that salt pickup can be described as a function of dilution (added water increasing transport capacity), erosion (separation of sediment particles from natural formations), dissolution (separation of the salt ions from the sediment particles), and an interaction of the three. He fit six empirical salt uptake equations to the observed data and achieved the best correlation ($r^2 = 0.64$) with the function:

$$TDS_t = B_o + B_1 P - B_r Q_s \quad \ldots\ldots \quad (1.17)$$

in which

TDS_t = Predicted salinity of the surface runoff
P = Precipitation rate
Q_s = Surface runoff rate
B_o, B_1, and B_r = Constants

Ponce (1975) concluded that the salt load that occurs with surface runoff is largely related to erosion. His quantitative analysis indicated that surface salt loading is not a unique function of rainfall intensity but also depends on many other unspecified factors. He also estimated that only 0.5 percent of the total salt loading at Woodside can be attributed to overland flow from natural areas.

Whitmore (1976) sampled Mancos Shale at nine different sites within the Price River valley. Based on laboratory analyses of these samples, he proposed that salt dissolution is diffusion controlled and that two distinct dissolution rates occur. One is a fast reaction in which 80 to 90 percent of the available salt is released from the shale surface within the first 2 minutes after runoff across it begins. A second slower reaction occurs as the remaining salt slowly goes into solution. The fast rates are attributed to indigenous salt on particles at the surface of the soil, and the slow rates are thought to reflect mineral weathering.

White (1977a) examined salt production from microchannels in the Price River valley. He documented the extreme surface mineral heterogeneity of the channels and described the salinity uptake in the channels as a rapid dissolution of surface salts followed by slow mineral weathering (very similar to the pattern Whitmore had previously found for overland flow). Based on measurements of dissolved salts and sediment, a linear predictive equation for salt load was developed. Good results were obtained; however, the equation is of limited practical application because sediment load is a difficult independent variable to measure or predict. He concluded that "microchannels contribute 3.4 percent of the total salt load of the Price River at Woodside."

CHAPTER II

THE PRICE RIVER BASIN

Topography

The Price River Basin, located primarily in Carbon and Emery Counties of east-central Utah, has a total drainage area of about 1850 square miles (Figure 1.1). The Price River flows 133 miles in a generally southeasterly direction from Scofield Reservoir and enters the Green River above the town of Green River, Utah. The basin elevation ranges from about 4,200 feet above mean sea level at its confluence with the Green River to 10,443 feet at Monument Peak in the western portion of the basin.

The dominant physiographic features of the basin are thg Wasatch Plateau, Book and Roan Cliffs, and the San Rafael Swell. On the west, the Wasatch Plateau rises abruptly from the Price River lowlands to a mean altitude of 9000 feet. Its sedimentary beds dip gently away from the San Rafael Swell located at the southern end of the basin. The swell is an asymmetrical anticline roughly 80 miles long and 30 miles wide. The region is known for its topography of concentric plateaus and massive cliffs. The Book and Roan Cliffs bound the north and east portions of the basin as they extend for 150 miles from West Central Colorado to Castle Gate and then south. Stokes and Cohenour (1956) have described the cliffs as consisting predominantly of shales and sandstone marked by deep canyons and finger-like gravel-capped benches. The weathering gravel caps vary in thickness from 50 feet at the base of the mountains to a thin covering in the valley. Much of the cap area is cultivated, but production levels on many of the farms have deteriorated because of salt accumulation in the soil.

Geology

The geology of the Upper Colorado River Basin is the dominant factor determining the occurrence, behavior, and chemical qualities of its water resources (Hyatt et al. 1970). Surface rocks and soils of marine shale origin are the predominant source of stream salinity (Mundorff 1972).

An extensive marine formation, known as Mancos Shale, has been identified as a major natural contributor of salts to the Colorado River. The formation, which underlies approximately 25 percent (470 mi^2) of the Price River drainage, is approximately 5000 feet thick and dips generally concentrically away from the San Rafael Swell. The result is a U-shaped formation (with the top of the U pointing north), 10 miles widg, passing through the lowlands of the Price River Basin.

The Mancos Shale is classified into three main shale members--Masuk, Blue Gate, and Tununk--which generally are separated by sandstone layers (Figure 2.1). In locations where the separating layers of sandstone are missing, the shale is termed "undivided."

The Mancos Shales were deposited during the late Cretaceous period by shallow, highly saline inland seas (Stokes and Heylman, no date). During the early Cretaceous Period, marine formations were restricted to northern Utah, while the non-marine Dakota and Cedar Mountain formations were forming in central and southern Utah. When the seas reached Eastern Utah during the Cenomanian epoch, the Mancos Shales were formed. The dominant geologic tendency during this epoch was one of subsidence and shale deposition, but there was at least one intervening period of sand accumulation, represented by the Ferron Sandstone. The clastics formed as the seas were crowded eastward by deposition resulted in complex sequences of near shore sediments, the most important being the Star Point, Garley Canyon, and Emery Sandstone

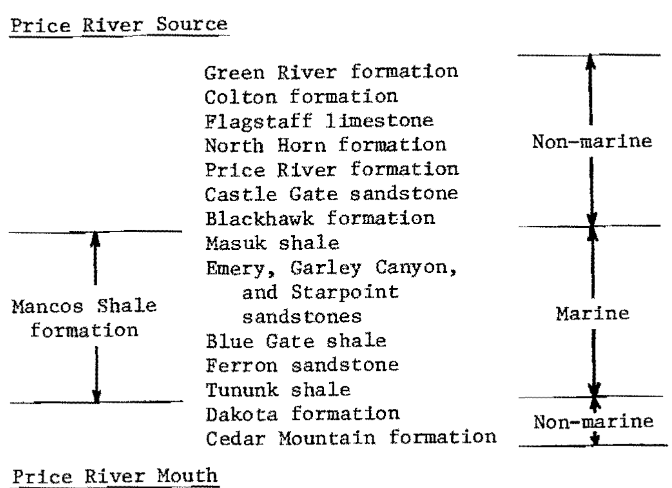


Figure 2.1. Predominant geologic formations of the Price River Basin.

Formations. These clastics grade eastward into the shales. As the Cretaceous Period drew to a close, central Utah emerged from the sea, and the later formations are all nonmarine.

The Price River headwaters in the Green River Formation. Most of the river flow, approximately 85 percent, originates in the Wasatch Plateau and from the Book and Roan Cliffs (Utah Division of Water Resources 1975). The river traverses the newer nonmarine formations until reaching the Mancos Shales at Castle Gate. From there the river traverses the Mancos formations to Woodside.

The three major formations of the Mancos Shales (Masuk, Blue Gate, and Tununk) are separated in places by the sandstone tongues (Figure 2.2). The marine shales are described as drab and slightly bluish-gray and contain some thick lenses of calcareous sandstone, limestone, and concretionary beds. The shales characteristically vary greatly in salt content and are relatively impermeable and erodable. Burge (1974) attributes the impermeability of the shales to the fineness of the contained clays and the rapid weathering to cyclic dehydration-hydration of the entrained salts, particularly mirabilite ($Na_2SO_4 \cdot 10H_2O$) and thenardite (Na_2SO_4).

At elevations above 7,000 feet, average annual precipitation varies between 30 inches and 12 inches and mostly occurs during the winter (Mundorff 1972). Precipitation on the river valley averages less than 10 inches annually, and most rainfall is during the late summer. These summer and fall storms produce almost all of the surface runoff and erosion on the valley floor. Average precipitation and temperature data for selected stations are given in Table 2.1.

Summer storms are typically short duration thunderstorms while most winter precipitation comes from relatively low intensity frontal storms. During the winter, frontal storms from the Gulf of Alaska produce snowpacks in the surrounding uplands. Thunderstorms during the late summer months develop as warm moist air from the Gulf of Mexico moves into the valley. Monthly distributions of precipitation at selected stations are given in Table 2.1.

On the highest 30 percent of the area, about 65 percent of the precipitation falls from October through April, and most of it is snow. The spring melt provides irrigation water for agriculture.

Streamflows

Most of the outflow from the Price River Basin originates as snowmelt. The summer thunderstorms are usually of short duration, localized, and intense. Surge flows can develop in the valley channels, eroding and transporting large masses of sediment. Most tributary streams become completely dry during low flow periods.

Average annual yield for the Price River Basin ranges from less than 1 inch in the valley to over 12 inches in the mountains (Figure 2.3). Although about 50 percent of the total basin is below 6,400 feet, only 10 percent of the total water yield originates from these lower elevations. Annual runoff from the Price River valley is estimated to be 1.08 inches or about 9 percent of the average annual precipitation of 11.7 inches.

Streamflow in the principal streams is highly regulated. Most summer flows are diverted for use within the basin. Scofield Reservoir (capacity 45,000 acre-feet), located near the headwaters of the Price River, stores runoff for release during the irrigation season.

Jeppson et al. (1968), using the Thornthwaite formula, estimated the evapotranspiration for the valley to generally exceed 24 inches annually. This is about 2.5 times the precipitation, and thus irrigation is used to make up for the moisture deficient in agricultural areas. Water enters the valley floor from the river and tributaries and as imports. Approximately 28,000 acre-feet per year are imported from Huntington Creek

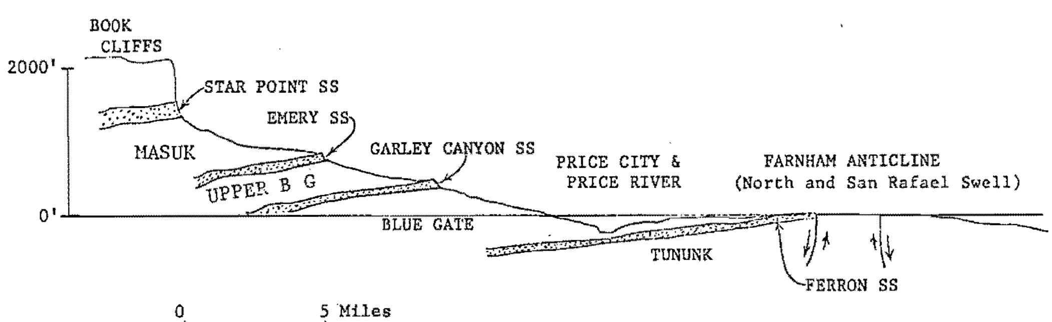


Figure 2.2. Mancos Shale cross-section (taken from Williams 1975).

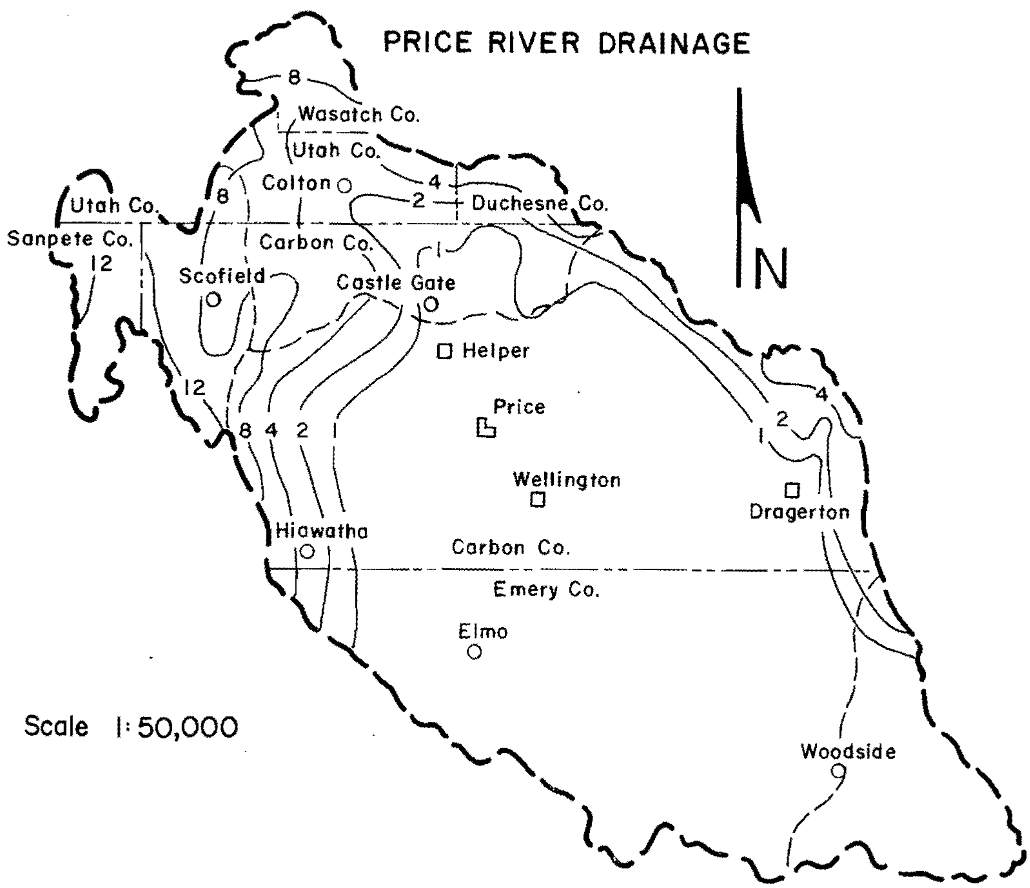


Figure 2.3. Mean annual water yield in inches (Utah Division of Water Resources 1975).

in the San Rafael Basin. Consumptive use occurs in municipalities, irrigated areas, and natural wetlands. About half of the inflow leaves the basin as river outflow at Woodside. Figure 2.4 depicts the estimated mean annual water budget.

Table 2.2 shows the mean monthly flows at selected gaging stations. In the central basin, only Desert Seep Wash is gaged. In total, the tributaries contribute approximately 39,000 acre-feet of water per year to the valley.

Water quality

The streams within the upland canyons generally contain relatively high quality water of less than 500 mg/l. Except for periods of high snowmelt runoff, all of the Price River lowland tributaries contribute low quality water (Mundorff 1972). Otherwise, the streams show no significant seasonal variation in total dissolved solids concentration.

Within the valley stream channels, efflorescence (salt crusted around the channel periphery) accumulates during periods of low flow. During periods of runoff, the efflorescence is dissolved and flushed into the stream.

Mundorff (1972) regards diffuse agricultural return flows as a probable major source of salt input to the Price River. Williams (1975) hypothesized that a major salt loading source was the surface runoff from rains and snow over the Mancos Shale badlands. He also discusses the possibility of saline flow from the sandstone clastics and identifies coal processing as another possible major contributor.

In the upper Price River drainage, suspended solids are not a problem; but in the valley, concentrations as high as 64,800 mg/l have been recorded. On one day when samples were taken along the Price River, total suspended solids ranged from 180 mg/l above Scofield to 226 mg/l at Heiner and 2,119 mg/l at Woodside (Mundorff 1972).

Table 2.1. Mean monthly and annual temperatures and precipitations for stations in the Price River drainage area (Utah Division of Water Resources 1975).

Station No.	Station Name	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
							Temperature (°F)							
1214	Castle Dale[a]	47.6	33.2	24.0	18.2	25.0	37.5	46.8	54.8	64.3	70.4	68.2	59.4	45.8
7015	Price Game Farm	51.3	36.9	27.0	22.7	29.9	39.0	48.4	57.7	66.8	73.3	71.2	63	48.9
7724	Scofield Dam	42.1	27.5	17.8	13.2	16.2	25.1	36.1	46.0	54.6	61.1	59.6	52.7	37.7
1472	Clear Creek	40.7	28.4	22.8	19.4	20.7	26.2	35.2	44.0	52.1	58.7	57.7	50.5	38.0
3896	Hiawatha	47.8	33.8	26.0	23.0	26.7	33.5	43.6	52.5	62.2	69.1	66.7	59.4	45.4
7959	Soldier Summit	41.6	28.3	21.1	17.6	20.9	28.2	38.1	46.2	53.4	61.3	60.1	52.5	39.1
3413	Green River[a]	54.3	37.5	28.4	22.8	32.5	43.3	54.2	63.8	72.5	80.7	78.0	68.4	53.0
							Precipitation (In.)							
1214	Castle Dale[a]	0.86	0.54	0.60	0.69	0.61	0.54	0.54	0.57	0.48	0.88	1.16	0.92	8.39
7015	Price Game Farm	0.96	0.54	0.88	0.73	0.65	0.66	0.61	0.70	0.67	0.90	1.11	0.83	9.24
7724	Scofield Dam	1.08	1.17	1.43	2.66	2.13	1.48	0.98	1.09	0.88	0.94	1.29	0.96	16.04
1472	Clear Creek	2.02	1.70	2.41	2.65	2.69	2.68	1.95	1.57	1.43	1.53	1.56	1.34	23.53
3896	Hiawatha	1.33	0.78	0.96	1.00	0.89	0.97	0.91	1.08	0.95	1.18	1.84	1.00	12.87
7959	Soldier Summit	1.06	1.07	1.51	1.50	1.70	1.54	1.01	1.10	0.62	1.17	1.38	1.06	14.72
9629	Woodside	0.88	0.73	0.48	0.50	0.39	0.39	0.64	0.52	0.48	0.49	0.91	0.66	7.05

[a]Not in Price River Basin.

Table 2.2. Mean monthly and annual runoff for stations in acre feet in the Price River drainage area (Utah Division of Water Resources 1975).

Station #	Name	Period of Record	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Annual
3095	Fairview Ditch near Fairview, Utah [1]	1950-1966	---	---	---	---	---	---	---	9.2	325.4	536	363.1	100	1,334
9-3117	Price River near Soldier Summit, Utah	1962-1963	629.3	680.5	767	351.5	336	392	875	4,395	7,905	11,275	6,530	3,515	37,651.5
9-3127	Beaver Creek near Soldier Summit, Utah	1961-1966	29	29	21.8	25.1	31.2	84.9	395	1,056.3	569.6	164.4	56.7	38.8	2,502
9-3128	Willow Creek near Castle Gate, Utah	1963-1966	99.4	71.1	35.7	40.9	73.5	434.8	1,059	23,665	863.3	466.3	237.2	161.5	5,909.2
3140	Price River near Wellington, Utah	1950-1958	1,957	1,673	1,451	1,381	1,675	2,623	8,743	17,149	8,378	3,180	4,268	2,157	56,635
3145	Price River at Woodside, Utah	1946-1966	4,491	3,593	2,505	1,909	3,036	7,617	10,568	15,301	7,355	5,007	7,753	6,297	75,439
3125	White River near Soldier Summit, Utah	1938-1966	228	208	181	165	167	344	3,283	6,217	1,688	560	292	215	13,598
3105	Price River Above Scofield Reservoir	1939-1966	640	616	525	461	432	636	3,630	15,472	6,622	1,683	882	591	32,190
3130	Price River near Heiner, Utah	1934-1966	2,635	1,069	742	591	714	2,289	9,725	20,863	13,410	11,167	7,436	5,042	75,743
3115	Price River near Scofield, Utah	1918-1966	1,696	411	292	154	210	211	1,435	8,852	9,580	9,145	6,060	4,156	42,202
3100	Gooseberry Creek near Scofield, Utah	1940-1966	281	256	208	177	168	230	1,172	6,078	3,109	852	498	304	13,333
*3110	Scofield Reservoir near Scofield, Utah	1942-1966	14,418	14,527	15,179	16,310	17,413	18,862	21,924	33,225	36,986	30,860	23,655	18,827	

*End of Month Reservoir Storage

[1]Does not drain into Price River

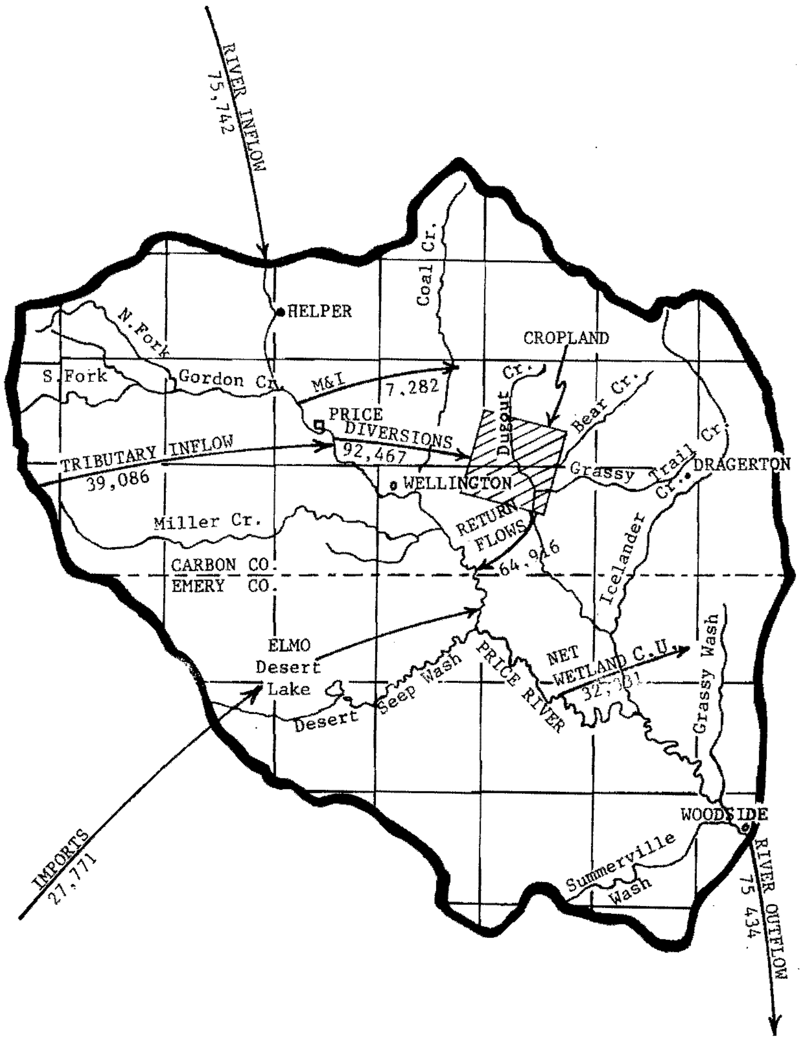


Figure 2.4. Price River Valley estimated annual water budget in acre-feet/year. (Taken from Utah Division of Water Resources 1975).

Groundwater

The use of groundwater within the central basin is limited by the quality of the water available. Total dissolved solids have ranged from 3,600 to 73,000 mg/l in exploratory wells. Only the best of this water is useful even for stock watering.

Above the central basin primarily in the Colton area, groundwater is of high quality. Cordova (1964) estimated that approximately 3,000 acre-feet per year of groundwater presently were being withdrawn by pumping and by outflow from springs and seeps. He also estimated that an additional 4,000 acre-feet per year of groundwater resources could be developed. Clyde et al. (1981) described groundwater quantity and quality in Pleasant Valley just upstream from Scofield Reservoir.

Vegetation

The principal vegetative types on natural or uncultivated lands in the basin are Yellow Pine and Douglas Fir in the headwater areas, Pinyon-Juniper on the gravel caps of the lower slopes, and Shadscale-Sagebrush in the valley bottoms (Mundorff 1972). It is from these Shadscale-Sagebrush lands that the vast majority of the salt pickup by overland and microchannel flow occurs.

Economy

The leading industry of the Price River Basin is coal mining. Through the 1960s and early 1970s, coal mining and population declined. As a result of the recent "energy crisis," utilization of coal reserves has increased. Continued population growth is expected.

Farming is the second most important industry in the basin. As shown in Table 2.3, agriculture is principally for livestock production. Both coal and agriculture require substantial water supplies, and both have return flows that can be detrimental to water quality.

Table 2.3. Farming types and percent of total in the drainage.

Type of Farm	Percent of all Farms
Sheep	40
Beef	23
Beef and sheep	22
Cash crop	8
General	4
Dairy	3
	100

CHAPTER III

STUDY METHODS AND PROCEDURES

Scope of the Study

Previous examinations of salt loading processes and of the mechanisms within them have been largely qualitative or based on statistical analysis of empirical data. Theoretical relationships have been proposed, but available data have been limited for their calibration and integration into models. In searching for sites where data could be collected to support model improvement, three situations seemed to merit particular examination:

1. Streams originating in upland areas and then flowing onto the lowlands to collect salt from diffuse natural sources in Mancos Shale areas.

2. Natural channels with weathered Mancos Shale material in their beds.

3. Natural channels where seepage enters through their banks or beds, evaporates, and leaves salt deposits known as efflorescence.

Stream Surveys and Reconnaissance

Examination of the Price River Basin was begun during the summer of 1975 with the objectives of identifying significant diffuse natural salt source areas and of identifying promising study streams. During a second season of field work, emphasis was to be placed on monitoring the water quality on selected streams in an attempt to assess the major salt uptake mechanisms. In addition to looking for the three situations described above, it was also considered desirable 1) that discharge of agricultural drainage into the stream be minimal and 2) that the stream be reasonably accessible from the point of its emergence from the mountains or headwaters to its mouth.

Three streams were initially considered for detailed study, namely, Icelander Creek, Brushy Springs Wash, and Cedar Creek (Figure 1.1). Weekly flow and water quality measurements were made on each creek from July 16 to August 26, 1975. The streams flow over the Mancos Shales and were expected to exhibit generally high salt loads. Flows were estimated with rectangular cutthroat flumes (Skogerboe et al. 1967). The following additional equipment was used for field measurements:

1. Yellow Springs S-C-T conductivity meter, model 23 (conductivity)

2. Marsh McBirney water current meter, model 201 (flows)

3. 60° V-notch weirs (low flows)

4. Digi-sense digital pH meter (pH)

5. U. S. Weather Service thermometers (temperature)

Most samples were analyzed chemically by the College of Eastern Utah chemical laboratory. The remaining chemical analyses were conducted by the Utah Water Research Laboratory, unless otherwise stated. Appendix A describes the chemical methods and procedures used. The data obtained from observations on Icelander Creek, Brushy Springs Wash, and Cedar Creek are reported in Appendix B (Tables B.1, B.2, B.3).

Cedar Creek exhibited very little flow variation or salt pickup from channel processes and had an average flow of less than 0.1 cfs and an average TDS of 3,500 mg/l during the sampling period. The stream was easily accessible, but due to extensive channel work for flood control, it could not be regarded as a natural channel.

Brushy Springs Wash and Icelander Creek join below Highways 6 and 50. Observed flows varied from more than 100 cfs to less than 1 cfs in Icelander and from more than 50 cfs to 0.001 cfs in Brushy Springs Wash. TDS varied from 350 mg/l to 7010 mg/l in Icelander and from 970 mg/l to 4830 mg/l in Brushy Springs Wash. Intense local thundershowers occurred over both streams on July 16, 1975, and again on July 29, 1975. During each storm event, the flow rose rapidly, TDS dropped, and suspended sediments increased rapidly. Unfortunately, only one set of samples was taken during each storm event. Like Cedar Creek, during steady flow conditions very little salt uptake was noted. Mainly because of poor access, this two-stream system also was rejected for further study.

To facilitate the search for a better study site, a basin-wide water quality survey was conducted on August 26, 1975. The survey covered 12 streams with 40 water quality sampling sites. The results are listed in

Appendix B (Table B.2). The flowing streams characteristically pick up salts as they move across the valley floor to the Price River. Many of the streams which drain wildlands contribute very little flow during the summer months.

The survey indicated that the salt load in the observed streams was large, with a mean TDS observation of 3650 mg/l and an observed high of 9800 mg/l. Under such high salt loadings, the springs may have reached saturation with regards to several significant minerals.

Coal Creek Instrumentation

Coal Creek (Figure 3.1) was chosen for instrumentation for detailed study. The Coal Creek catchment originates in the Book Cliffs, and the stream flows in a southerly direction to its confluence with the Price River near the town of Wellington. An upper control site (Figure 3.1) was located at the point at which the stream emerges from the Book Cliffs. The flow at this location is essentially perennial, with a baseflow of about 1 cfs during the snowmelt period declining to 0.1 cfs in the late summer. The average stream salinity at this point is about 500 mg/l. Dissolved salts are rapidly picked up with a TDS of 3420 mg/l measured at Highways 6 and 50 (Appendix B).

An 8.2 mile study section was chosen extending downstream from the base of the Book Cliffs. Access to the Coal Creek channel was gained from a paved road which is located adjacent to the channel on the west side, and which traverses the entire length of the study section. The catchment, except for a small irrigated farm, consists of natural lands.

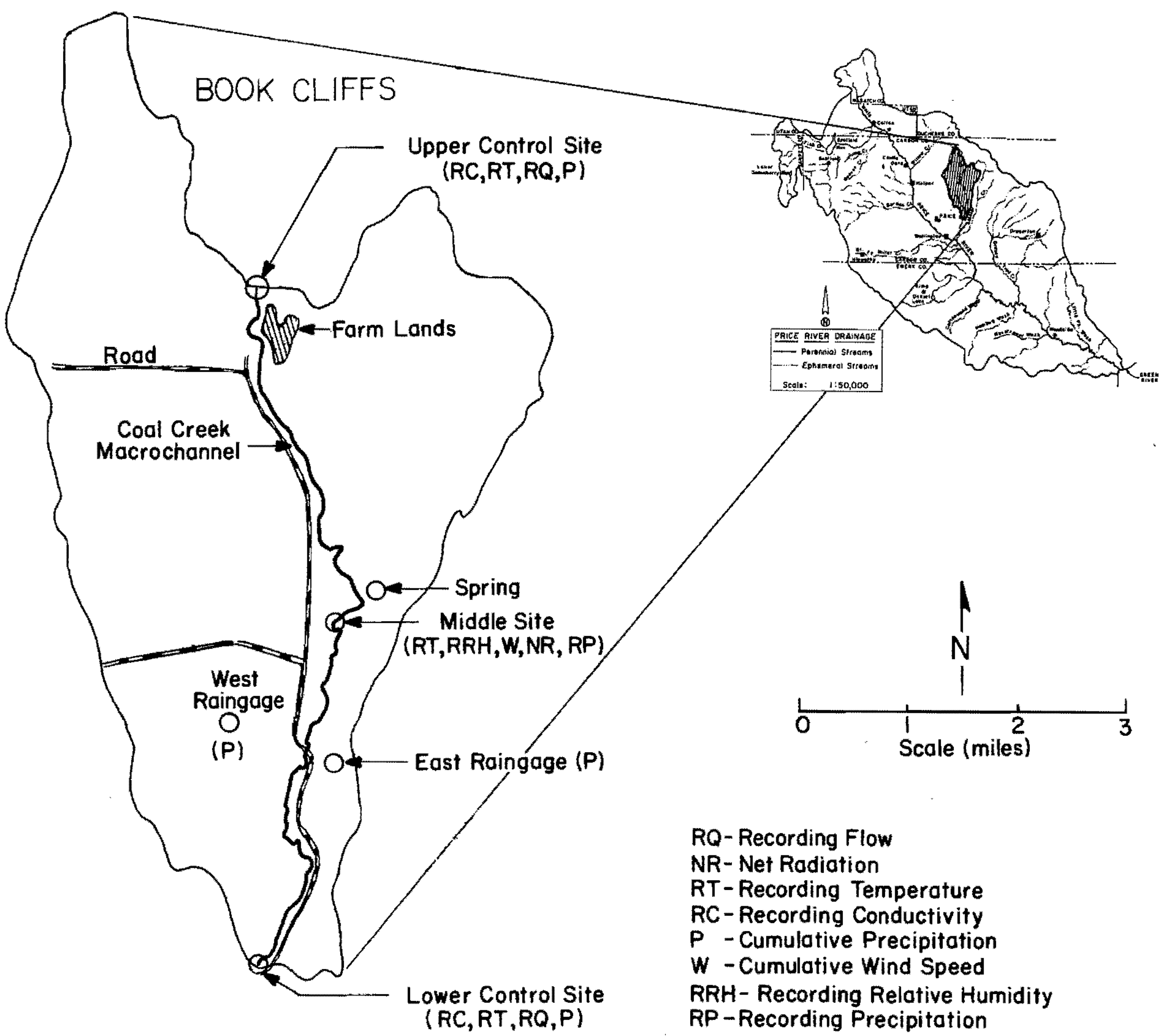


Figure 3.1. Coal Creek instrumentation.

The study section is underlain by undivided Mancos Shale (Ponce 1975). After the stream leaves the Book Cliffs, it meanders through a valley between steep clefted pediments on the east and west. The valley is approximately 3 miles wide and consists of rolling hills and pediment remnants. The terrain is dissected by numerous ephemeral streams that have cut deep and narrow channels through the easily eroded Mancos Shale. The vegetation is predominantly mixed sagebrush and grasses.

A small farm of approximately 180 acres (1.29 percent of the drainage area) is located along the base of the Book Cliffs. During much of the summer, the entire flow of the creek is diverted to irrigate alfalfa at a location immediately downstream from the upper control site (Figure 3.1). During diversion periods (except during runoff events), the channel is essentially dry for approximately 1.5 miles downstream. At this point, small quantities of flow (possibly return flows from the irrigated area) begin to accumulate in the channel. Further downstream, flows are augmented by tributary inflow. Conductivity measurements during the summer of 1975 indicated a general increase in the salinity of the Coal Creek waters as the stream moved southward across the Mancos Shale.

Coal Creek was instrumented at the upstream and downstream control points (Figure 3.1) with the following equipment:

1. Recording Kernco model CR-15 conductivity meters.

2. Rustrack dual channel temperature recorders, model 2133.

3. Electronic staff gage recorders (constructed by Duard Woffinden, UWRL).

A third site was chosen near the middle of the study section and a staff gage installed. The following instruments were installed:

1. Belfort S/349A anemometer.

2. Casella thermo-hydrograph, #931.

3. Belfort recording raingage.

4. Micromet net radiometer, #R421 (damaged shortly after installation).

Four raingages (Figure 3.2) also were installed within the experimental drainage. Installation of the above equipment was completed on July 1, 1976.

Stream Sampling and Field Tests

Some samples were taken as early as May 1976, and regular weekly water quality sampling was begun in June. Sampling continued until December 1976. Channel soil samples were taken from 20 different sites (Figure 3.2). At each site, samples were taken at three depths from the channel bed and bank materials: 0-4 inches, 4-8 inches, and 8-12 inches. One-to-one saturation extracts were run on the samples by the Soils Laboratory at Utah State University. (Appendix A describes the methods used.) The data taken are recorded in Appendix C.

Field permeability tests were run in the main channel of Coal Creek. Four-inch diameter test holes were augered at a distance of 3 feet from the stream edge to a depth of approximately 3 feet. The channel bed was assumed to be saturated, and permeability was estimated from the recharge rate at the test hole (Bureau of Reclamation, undated). Test holes were dug at sites 1, 3, 5, and 9 (Figure 3.2).

A cable was strung across the lower site to aid in measuring streamflow during storm events. Apparatus and equipment for flow measurement and quality samplings, including sediment load, were stored on site. Because of the possible danger from flood flows, no field observations were made during major storm events.

To study salt pickup mechanisms under conditions of controlled channel flow, a small, natural ephemeral channel was selected which could be supplied with water at specific flow rates from an irrigation ditch. The channel is contained entirely in Mancos Shale and slopes southward at approximately 2.5 percent. Water was released from a small flume which conveys irrigation water over the natural channel. HS flumes (USDA 1962), equipped with Leopold and Stevens model 61, 12-hour recorders, were installed in the channel at four locations (Figure 3.3). Water conductivity measurements were made in the field. Sediment samples were obtained from the bottom of the flumes and filtered through GS/A 12.5-cm glass fiber filters. One-half of the samples were placed in 500 ml of distilled water and the conductivity monitored. The remaining sediment was left to air dry for later laboratory analysis. Flow was induced on two separate occasions, August 26 and September 9, 1976. On August 26, water quality samples were obtained in addition to flow and conductivity measurements. On September 9, only flow and conductivity measurements were made. During both tests, water was diverted down the channel until little salt pickup remained.

Prior to the above induced flows, 12 soil salinity sensors made by Soil Moisture Equipment Corporation (Model #5000A) were placed in the channel. Three sites were monitored (Figure 3.3) with sensors placed in the following manner:

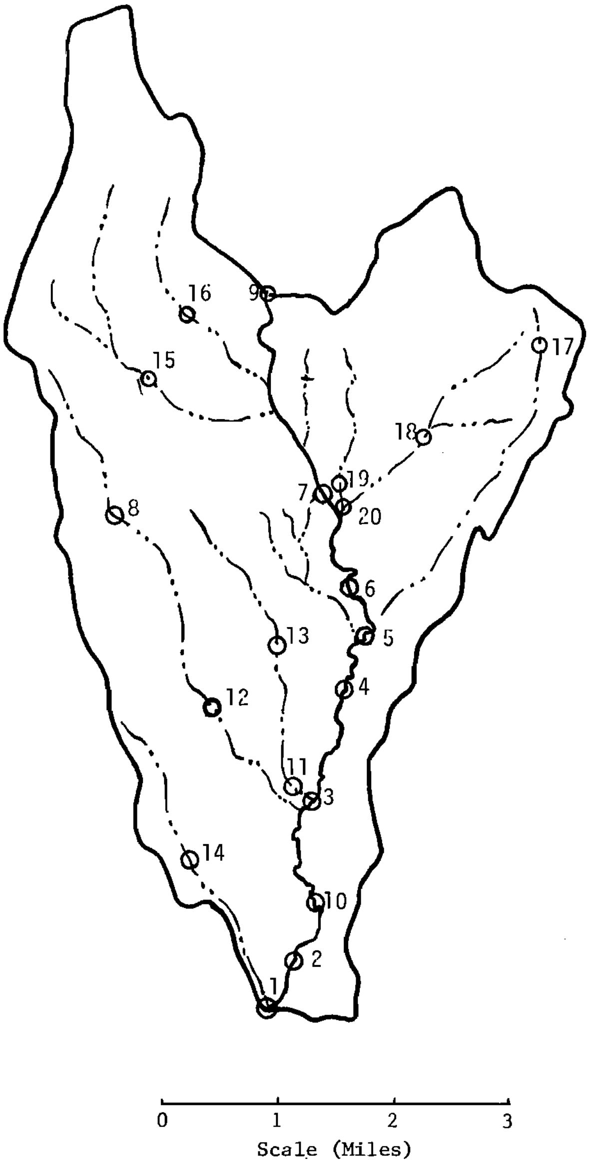


Figure 3.2. The Coal Creek study section showing ephemeral tributaries and soil samples sites.

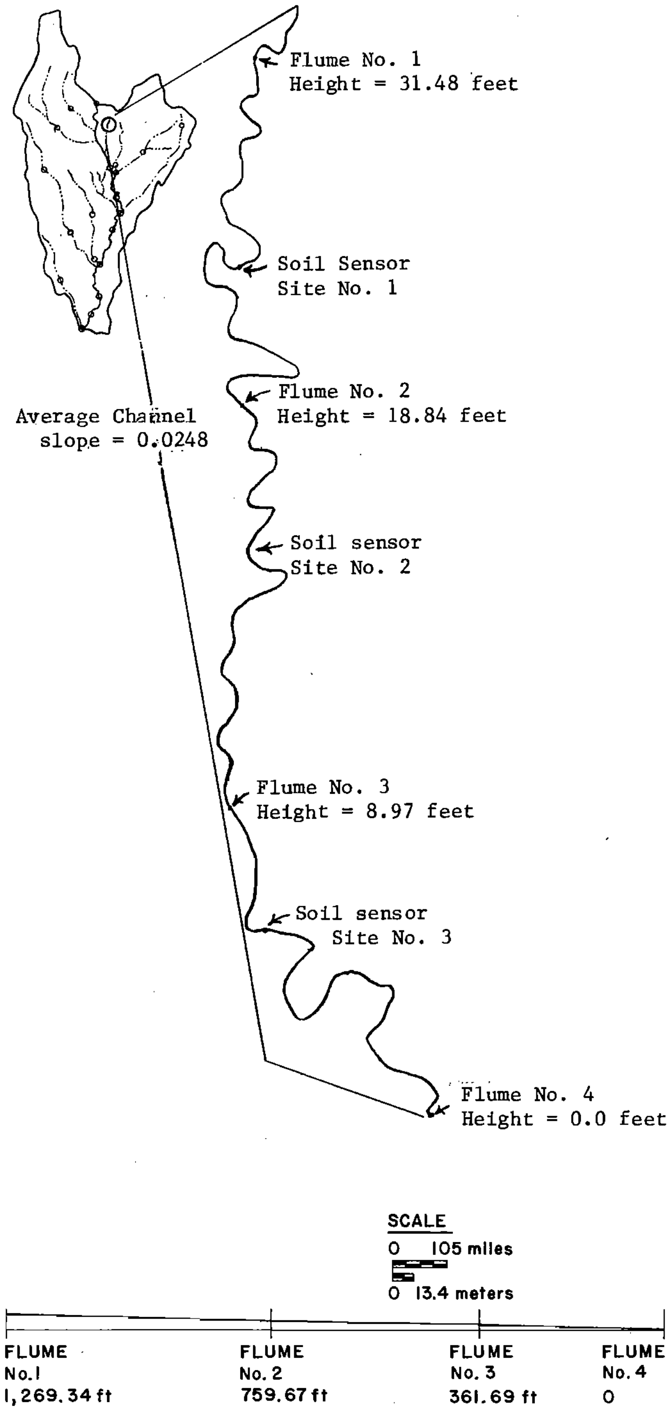


Figure 3.3. Channel configuration and instrumentation sites for the macro-channel study.

Site 1	Site 2	Site 3
Buried vertically in the channel bottom	Buried horizontally in the channel bank	Buried vertically in the channel bottom
6 cm depth	3 cm depth	4 cm depth
18 cm depth	13 cm depth	13 cm depth
29 cm depth	24 cm depth	23 cm depth
41 cm depth	36 cm depth	33 cm depth

The sensors were adapted to be monitored weekly with a Yellow Springs Model 33 conductivity meter.

At the beginning of each flow test, accumulated salt (efflorescence) was estimated by removing a 1-cm deep sample from the channel bottom at the three soil sensor sites. The samples were dried at 103°C for 24 hours, weighed, placed in 1 liter of distilled water, mixed for 1 minute, and settled for 30 seconds. The conductivity was then measured.

Laboratory Tests

To assist in defining in-channel salt pickup mechanisms, laboratory studies were proposed. The increased control over experimental variables in the laboratory was expected to define specific mechanisms more clearly than was possible under field conditions. The initial tests utilized a recirculating tilting flume charged with sediment obtained from channel bottoms in the Price River valley. The objective of the tests was to develop relationships of rates of salt dissolution versus flow.

Several problems were encountered: 1) mass movement of the sediment, 2) nonuniform flow, and 3) plugging of the recirculation system. The flume tests, therefore, were abandoned in favor of simpler sediment-jar tests. All data recorded during these laboratory tests are in Appendix D.

Potential salt contributions from both suspended sediment and bed-load were examined. Nine sediment samples were obtained from the macrochannel study (Figure 3.3). Each sample was halved in the field and removed from solution by vacuum filtering through a Whatman CF/A 12.5 cm glass fiber filter. One-half of the sample was placed in 500 ml of distilled water, and one-half was air dried. Prior to each measurement, the saturated sample was vigorously mixed, allowed to settle, and the conductivity was measured. The dried samples were weighed, sieved, and the grain size fraction calculated. The samples were then saturated with distilled water at a 1:1 weight ratio and the conductivity monitored as previously described.

To test if wetting and drying cycles increased salt release as suggested by Burge (1974), a simple test was designed. Shale samples were obtained from exposed formations at four sites within the Coal Creek drainage (Figure 3.1):

1. Macrochannel
2. Middle site
3. Spring
4. Lower site

Fragments passing a 1 3/8" sieve and retained upon a 1" sieve were rinsed with distilled water and dried at 103°C for 24 hours. The remaining portion of the four samples were divided into six subsamples; three for a control group and three for an experimental group. The subsamples were saturated with distilled water at a 1:1 weight ratio. Periodically, the temperature was measured, then the sample was gently stirred; and following settling, conductivity was measured. On days 2 and 43 from the beginning of the laboratory test, the experimental group was rinsed with distilled water and dried at 103°C for 24 hours. After drying, the samples were again saturated. On day 45, the control group was rinsed with distilled water and saturated.

To estimate the rate of salt release from the shale samples with respect to grain size and cyclic weathering, two tests were conducted. For both tests, the shale samples were separated into four size fractions by sieving (Appendix D, Table D-4). For the first test, six 10-gm subsamples from each size fraction (for a total of 96 subsamples) were obtained. The subsamples were saturated with 20 ml of distilled water and mixed in a Precision Scientific water bath and shaker (Model #66802) at 25°C for 30 seconds, 5 minutes, 30 minutes, 8 hours, 24 hours, and 72 hours, respectively. At the end of each time period a sample was removed, vacuum-filtered through a Whatman GF/A glass fiber filter, and the conductivity was measured with a Brinkman conductivity bridge.

For the second test, 50 gms of shale from each size fraction (for a total of 16 subsamples) were obtained. Each subsample was saturated with 100 ml of distilled water and placed within a Brinkmann rotoevaporator and an auxiliary (50°C) water bath, respectively. The rotoevaporator was rotated slowly for 15 minutes, after which 5 ml of supernatant was removed and filtered through a Whatman GF/A glass fiber filter. The conductivity of the filtrate was measured with a Beckman model RC-19 conductivity bridge. A vacuum was applied to the remaining sample, and the sample was rotated rapidly for approximately 1 hour or until completely dry. Distilled water (100 ml) was then added, and the process was repeated an average of four times for each subsample. The results of these analyses are also included in Appendix D.

CHAPTER IV

FIELD INVESTIGATION RESULTS FROM THE STUDY

Salinity and the Price River Basin

The time pattern in which the salt load is carried by the Price River results from a complex combination of interactions among time variable hydrologic processes. Natural groundwaters seep slowly into the stream to evaporate in the dry bed leaving encrusted salt behind. Waters diverted for irrigation leach salts from soil, and the return flows also add salt as the seep into the stream. Storm runoff hydrographs rise rapidly, picking up salts dissolved on the bed, churning bed sediments, and carrying the salts mixed with those sediments. After the storm, the flows recede rapidly, and the salts and sediments return to the bed a distance downstream from where they were before, determined by the size of the storm. Return flows work to keep the stream flowing through the dry season, carrying a more concentrated salt load, initially because of the salts leached from the soil and over the long run because of the consumptive use of water.

For general representation of the time patterns, daily flows and conductivities (a surrogate for total dissolved solids) are plotted for 1970 in Figure 4.1. As flow is an important factor determining salt transport, daily conductivities are plotted versus average daily flows for the Price River at Woodside for the 5-year period 1970-74 on a log-log basis (Figure 4.2). The line following the form of Equation 1.3 and having the best fit is shown on the figure and has a correlation coefficient of 0.648. The student t-test (Lapin 1975) showed the null hypothesis that the slope of the regression line was equal to zero to be rejected at the 99 percent confidence level. The conclusion at this point was that flow is definitely significant in determining salinity but that other factors also need to be considered.

According to Hendrickson and Krieger (1964), one needs to explore the different mineral dissolution characteristics of water flowing into the stream along various paths. Gunnerson (1967) explained the hysteresis in the annual pattern of monthly flows and conductivities for Columbia River subbasins in terms of the annual variation in dominant flow paths.

Discharge and salinity profiles along the Price River are shown by Figures 4.3 and 4.4, respectively, for data taken during a sampling survey on October 19 to 21, 1976 (Appendix B, Table B.3). Most of the flow was being diverted from the river above the City of Price (river mile 10). Downstream from the city, both the flow and the salinity increased rapidly. The predominant cations were sodium, calcium, and magnesium, and sulfate was the main anion. Figures 4.3 and 4.4 together suggest that the Price River salinity loading largely enters the stream by return flows and tributary inflows below Price.

To aid in identifying diffuse salt source areas in the Price River Basin, Mundorff's (1972) water quality samples of varying repetition at 71 sites over a 30-year period (Figure 4.5) were evaluated statistically. The sample sites were considered independent treatments, and mean salt loadings per sample site were calculated as pounds per day per square mile of drainage. The null hypothesis that the treatment means were equivalent was tested by comparing an individual treatment with the average of the remaining treatments. Student t-values were calculated (Neter and Wasserman 1974), but the results were not conclusive.

Three sampling sites, numbers 31, 50, and 52 (Figure 4.5), were identified as collecting runoff from areas of high salt loading. The three (Drunkards Wash, Desert Lake Wash, and Desert Seep Wash) drain irrigated farm land and exhibit a high average salt load, 518, 416, and 423 pounds per square mile of drainage per day, respectively. Drunkards Wash exhibited a large salt load in part because one of the sampling observations was made during a storm surge transporting a large flux of salt.

Figure 4.6 shows the major tributaries and canals in the proximity of Desert Seep Wash and Desert Lake Wash with average observed conductivity levels at measured points. As indicated by this figure, the average salinity level of the Price River increased by approximately 30 percent at its confluence with Desert Seep Wash. However, because of the strong influence of agriculture, Desert Seep Wash was not examined further in this study of salinity contributions from natural areas.

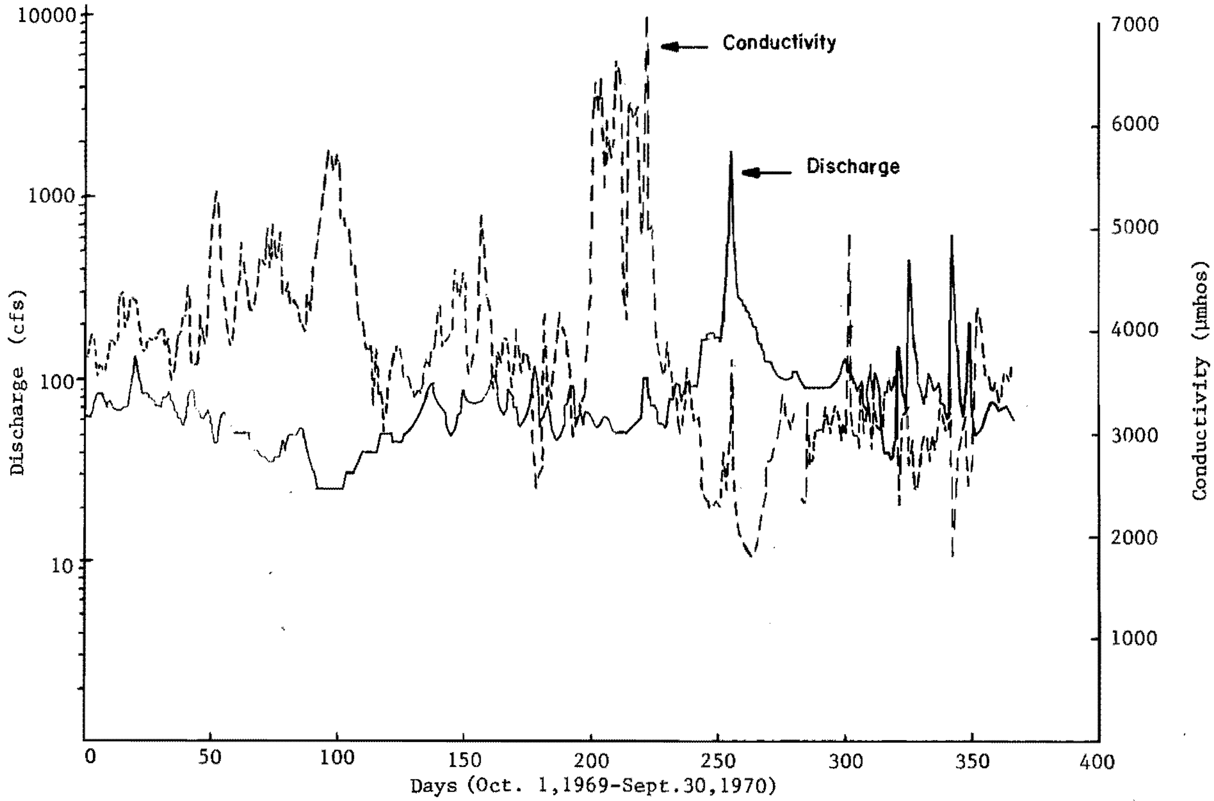


Figure 4.1. Discharge and conductivity versus date, from the Price River at Woodside. (Taken from USGS 1970).

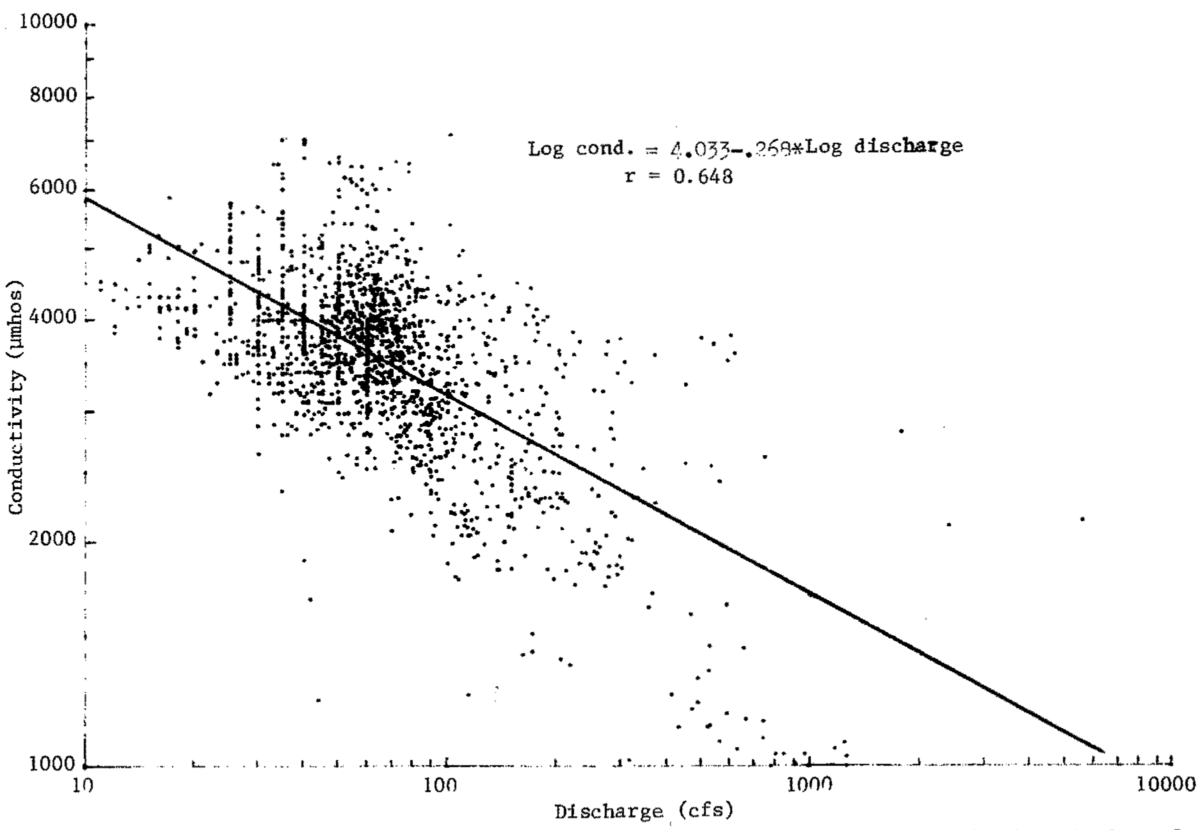


Figure 4.2. Conductivity versus discharge, for the Price River at Woodside. (Taken from USGS 1970-74).

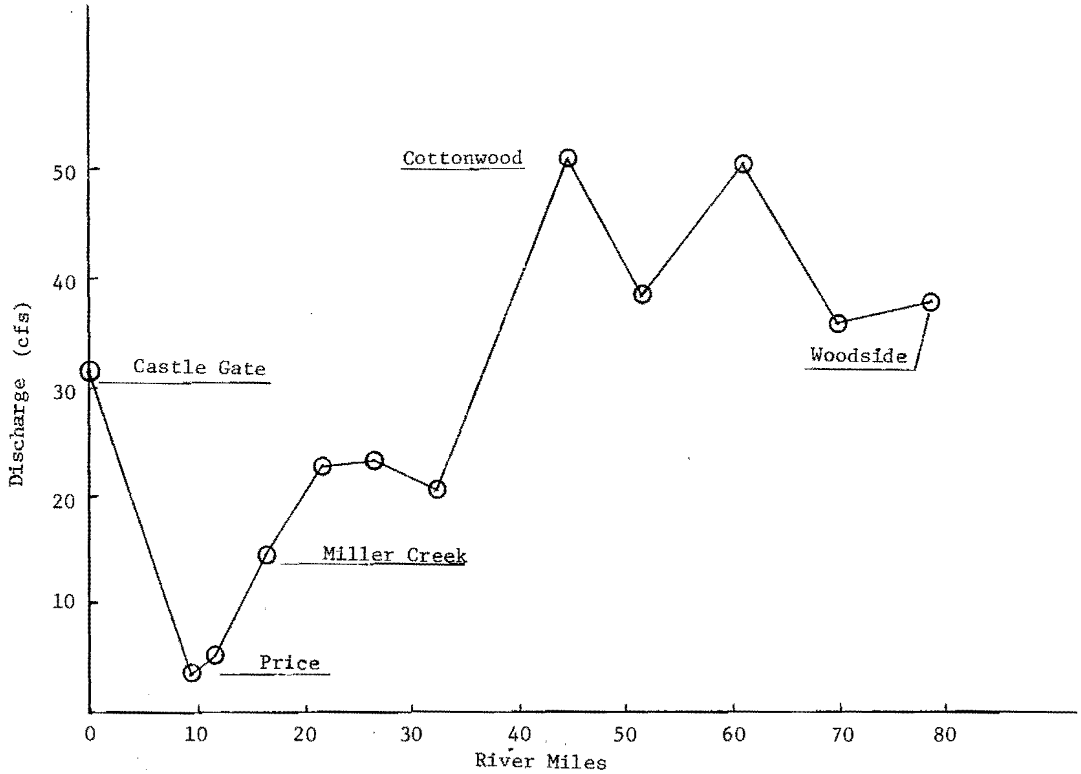


Figure 4.3. Price River flow profile for October 19 to 21, 1976.

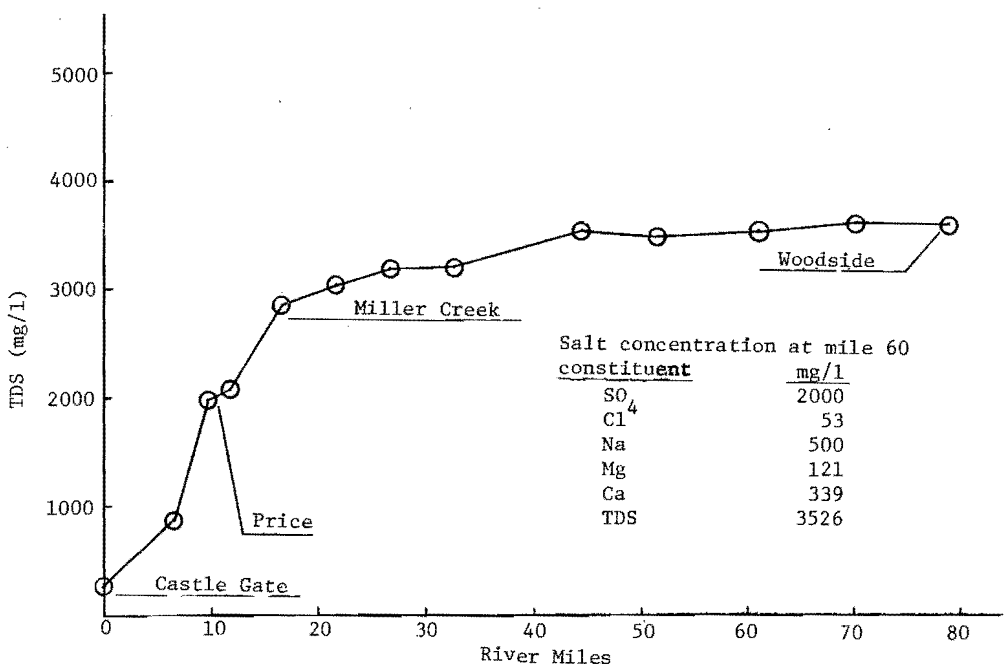


Figure 4.4. Price River salinity profile for October 19 to 21, 1976.

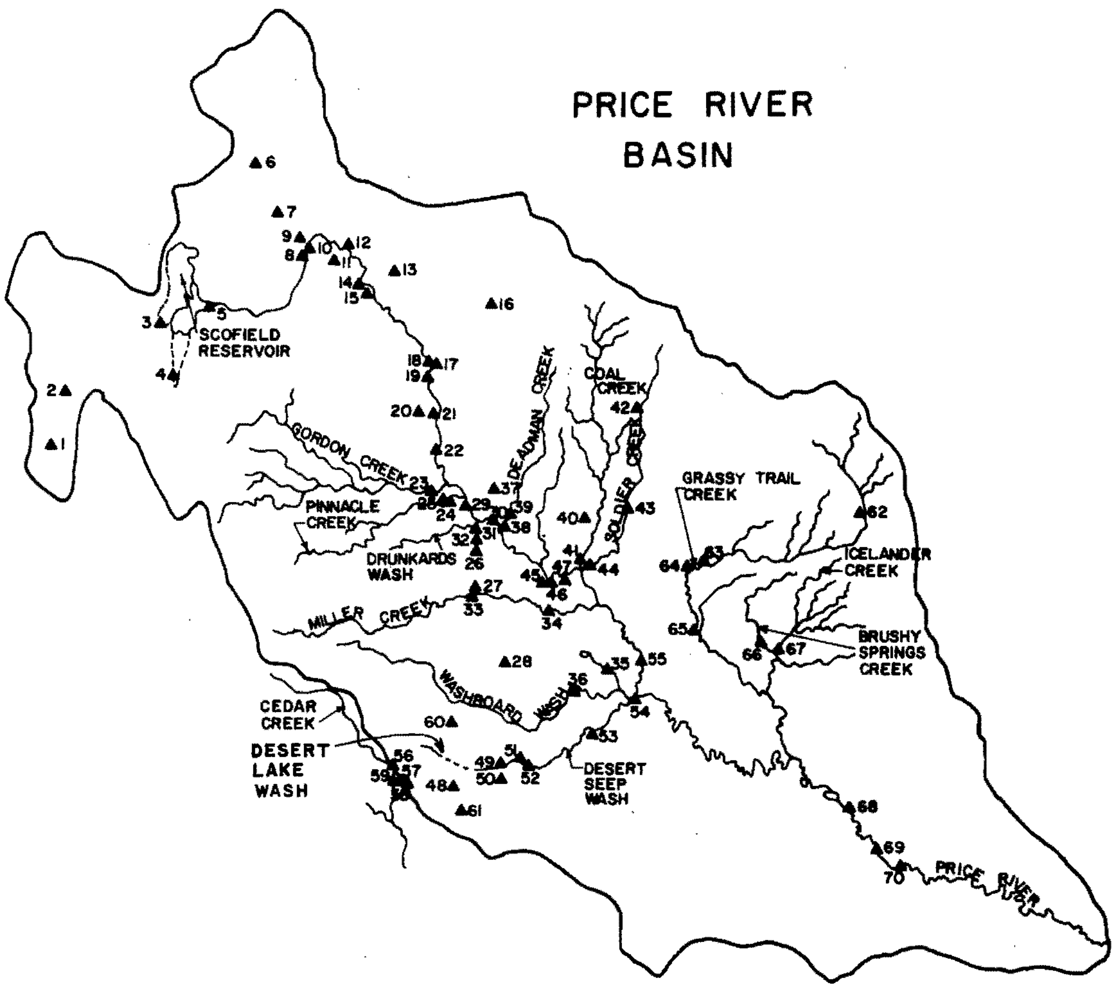


Figure 4.5. Price River Basin sampling sites listed by Mundorff (1972).

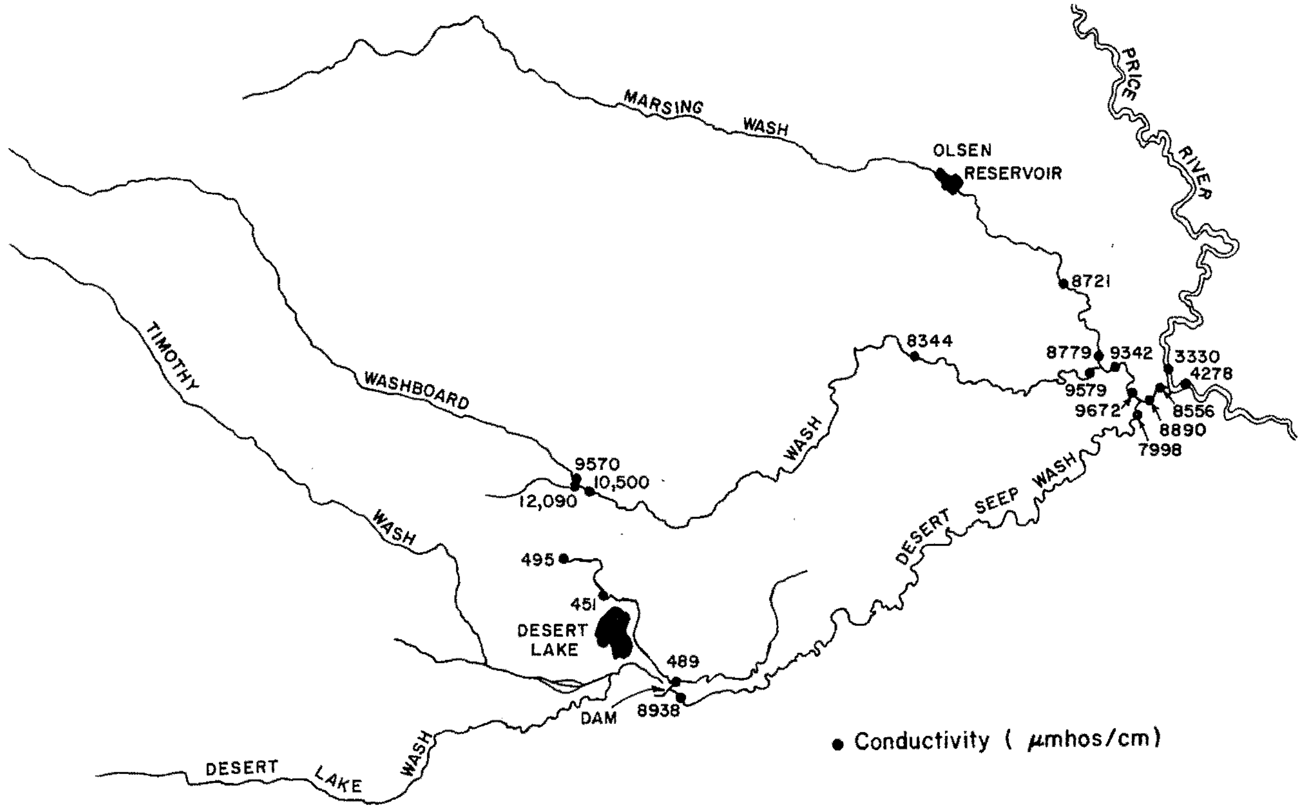


Figure 4.6. Desert Seep Wash vicinity map.

Coal Creek Study Area

Meteorology

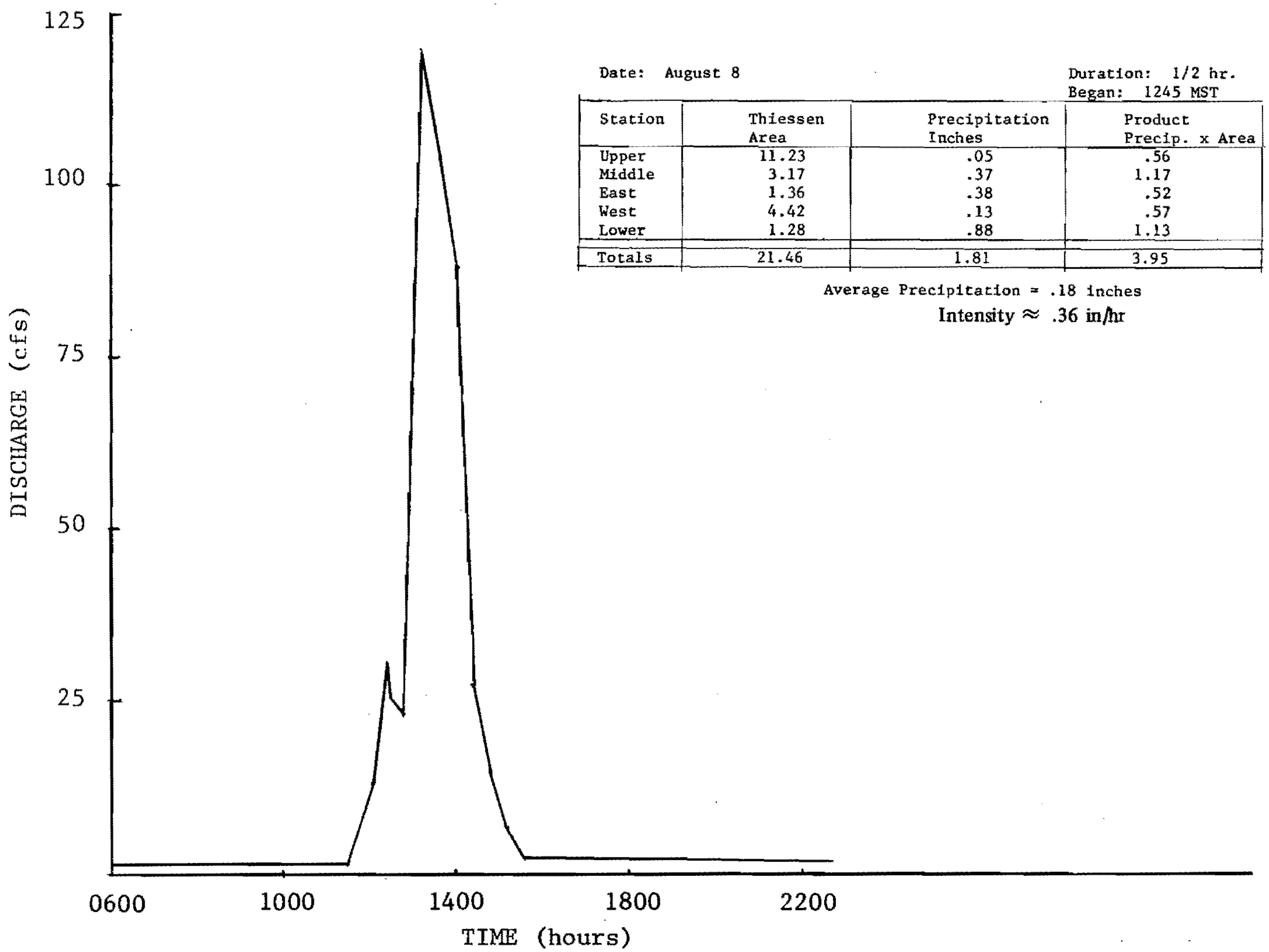
Meteorological data were collected weekly at Coal Creek from April to December 1976 (Appendix C, Table C-4). Observed daytime temperatures were as low as 34.5°F, but no snow was observed. Three local storms measured over 1.00 inch at the gage recording the largest amount, and the peak observed intensity at the recording gage was 0.35 inch in 15 minutes. The individual storms were localized and tended to be more intense during the spring and summer months. Rainfall measurements were averaged areally by Thiessen Weighting (Linsley and Franzini 1972) and totaled 4.40 inches for the 9-month period. The mean rainfall per event was 0.21 inch, with a standard deviation of 0.17 inch.

Coal Creek storm runoff

Over a dozen discrete storm events were recorded at Coal Creek during the study period of July to December 1976 (Appendix C, Table C-2). Six produced significant overland flow. The storms were characteristically localized and intense thunderstorms of short duration. Surface runoff was rapid. Surge waves were common. Rapid erosion caused large sediment loads. A small earth dam, diverting most of the normal flow at the upper site for irrigation, failed regularly during storm events. Operation of automatic field equipment under such violent flow conditions was difficult, and gaps in the observed data often occurred. Conductivity and stage probes were often swept downstream or buried beneath sediment.

On August 8, 1976, a rainstorm passed over the study section of Coal Creek. Average precipitation was 0.18 inch, and the storm duration was approximately 30 minutes. Little or no precipitation occurred upstream of the upper recording flow gage. The resultant recorded hydrograph is shown in Figure 4.7. The surface runoff was approximately 12 percent of the catchment average precipitation. From the hydrograph shape, surface runoff appears to have been rapid, with little bank storage or interflow occurring.

The corresponding measured conductivity in the streambed sediments peaked at 3200 μmhos/cm @ 25°C and then fell to about 1900



Date: August 8

Duration: 1/2 hr.
Began: 1245 MST

Station	Thiessen Area	Precipitation Inches	Product Precip. x Area
Upper	11.23	.05	.56
Middle	3.17	.37	1.17
East	1.36	.38	.52
West	4.42	.13	.57
Lower	1.28	.88	1.13
Totals	21.46	1.81	3.95

Average Precipitation = .18 inches

Intensity ≈ .36 in/hr

Figure 4.7. Lower Coal Creek flow hydrograph, beginning August 8, 1976.

μmhos/cm @ 25°C. The conductivity probe was buried under sediment, and a delayed response masked the shape and timing of the halograph. While some sediment induced error is probable, the above maximum and minimum conductivity values are close.

Coal Creek flow and quality measurements

Conductivity and flow measurements made on Coal Creek during 1976 are plotted on Figures 4.8 to 4.15 inclusive for sites shown on Figures 3.1 and 3.2. The average observed streamflow in Coal Creek, below the Book Cliffs, declined from 1.5 cfs in April to 0.25 cfs in August (Figure 4.9). The mix of anions and cations at the upper site was fairly constant (Appendix C, Table C-2). Conductivity increased from an average of 750 μmhos/cm at 25°C in April to 1000 μmhos/cm at 25°C in October with measurements made every 30 days (Figure 4.8). Sharply lower values of conductivity were observed after a storm event. This is attributed to the dilution effects of overland flow and to the low quantities of residual salts held in the sediments of the Coal Creek channel.

Linear regression analyses were applied to estimate six chemical constituents using conductivity as the independent variable. The t-test was used to test the null hypothesis that the slope of the regression line equals zero.

$$Y = a + b\,[\text{Conductivity}] \quad . . . . . (4.1)$$

in which

Y = TDS or individual ion concentration
a and b = Constants

The results are shown in Table 4.1. The low correlation coefficients were due primarily to grouping of the observed values within a very small range; this is particularly evident at the spring where the quantities of flow and chemical constituents varied in too small a range for meaningful regression to be possible.

At no time were overland return flows from the irrigated land associated with an increase in conductivity of more than 10 percent of that measured at the upper site. Because of seepage, the flow diminished and often disappeared in the 3-mile section below the upper site (Figure 3.1). Approximately 3 miles below the Book Cliffs, water enters Coal Creek from numerous small seeps and one large spring. The source and the extent of the aquifer supplying the seeps and spring are unknown (Gwynn 1976).

Discharge and water quality at the spring were monitored. Flow (Figure 4.11) was observed to peak at 0.1 cfs during April and to steadily decline to 0.04 cfs during December. Conductivity (Figure 4.10) remained stable with an observed mean of 2759 μmhos/cm at 25°C and a standard deviation of 235 μmhos/cm at 25°C. Data presented in Appendix C (Table C-2) also show that the concentrations of the chemical ions in the spring discharge were nearly constant.

The middle sampling site was located approximately 3.25 miles below Coal Creek's emergence from the Book Cliffs (Figure 3.1). The observed flows were generally low, except following storm events, and came from the spring and seeps immediately upstream (Figure 4.13). The conductivity ranged from approximately 1000 μmhos/cm at 25°C to 3200 μmhos/cm at 25°C (Figure 4.12). The large variation in conductivity was due to dilution by storm runoff. At low flows, the majority of the flow originated as groundwater of approximately 2760 μmhos/cm at 25°C. At high flows the majority of the flow originated as surface runoff from either the upper part of the subbasin or above the upper site and exhibited little channel salt uptake. Particularly high correlations with conductivity (Table 4.1) were obtained at this site for TDS and sulfate.

The flow at the lower site, 8.2 miles downstream from the Book Cliffs (Figure 3.1), was highly ephemeral (Figure 4.15). Much of the flow passing the middle site was lost through channel seepage and evaporation between the two sites. During periods of continuous flow, very little salt uptake occurred in the Coal Creek channel, and the conductivity of the lower site approached that of the upper site (Figure 4.14). During periods of low flow, when groundwater represented the major source of flow, the conductivity equaled or exceeded the mean groundwater conductivity. From Table 4.1 high correlation coefficients (Equation 4.3) were obtained for TDS, sulfate, magnesium, and chloride. The null hypothesis was rejected at the 0.99 confidence level for all seven regressions.

Mean measured values of anions and cations at each site are listed in Table 4.2. On a given date, TDS measurements at the middle and lower sites usually were very close (Appendix C, Table C.2). The smaller mean value of the TDS at the lower site (Table 4.2) is explained on the basis that a larger number of samples were taken at this location than at the middle site during spring runoff.

Salinity from the Coal Creek channel sediments

The natural channel bottoms in the Coal Creek basin are composed of unconsolidated bed material and exposed Mancos Shale. The channels display surface efflorescence varying from a dense white blanket to intermittent small discrete deposits. Mass transport of the channel bed material by major storm events was observed during the study reported here and by Mundorff (1972). During relatively steady and uniform low flow

Table 4.1. Linear regression analysis of chemical constituents versus electrical conductivity from four observation sites on Coal Creek.

Comparison	Constants in Eq. 4.1: a (mg/l)	Constants in Eq. 4.1: b (mg/l/µmhos/cm)	r^2	t	Degrees of Freedom	Level of Significance
Upper Site						
TDS vs. Conductivity	36.03	0.582	.489	6.105	41	**
$SO_4^=$ vs. Conductivity	-38.23	0.230	.650	8.502	41	**
Cl^- vs. Conductivity	10.23	0.003	.016	.812	41	NS
Ca^{++} vs. Conductivity	-71.00	0.157	.337	4.457	41	**
Mg^+ vs. Conductivity	-1.92	0.035	.196	3.080	41	**
Na^+ vs. Conductivity	4.41	0.089	.432	5.587	41	**
Spring						
TDS vs. Conductivity	3300.65	-0.425	.074	-1.203	18	NS
$SO_4^=$ vs. Conductivity	260.16	0.340	.019	.635	21	NS
Cl^- vs. Conductivity	86.77	-0.028	.057	-1.103	20	NS
Ca^{++} vs. Conductivity	99.27	0.030	.002	.173	19	NS
Mg^+ vs. Conductivity	-48.34	0.044	.017	.576	19	NS
Na^+ vs. Conductivity	1213.82	-0.305	.080	-1.286	19	NS
Middle Site						
TDS vs. Conductivity	-311.93	0.857	.864	11.310	20	**
$SO_4^=$ vs. Conductivity	-558.95	0.630	.883	12.299	20	**
Cl^- vs. Conductivity	27.27	-0.002	.011	-.474	21	NS
Ca^{++} vs. Conductivity	-121.56	0.119	.174	2.054	20	NS
Mg^+ vs. Conductivity	6.18	0.024	.173	2.044	20	NS
Na^+ vs. Conductivity	-19.72	0.130	.347	3.338	21	**
Total Hardness(Y) vs. Conductivity (X)	-108.89	0.312	.609	5.725	21	**
Lower Site						
TDS vs. Conductivity	-218.07	0.843	.954	24.98	30	**
$SO_4^=$ vs. Conductivity	-298.24	0.548	.941	21.43	29	**
Cl^- vs. Conductivity	-2.67	0.016	.838	12.66	31	**
Ca^{++} vs. Conductivity	2.72	0.035	.201	2.789	31	**
Mg^+ vs. Conductivity	-9.85	0.030	.518	5.771	31	**
Na^+ vs. Conductivity	-65.11	0.156	.554	6.205	31	**
Total Hardness (Y) vs. Conductivity (X)	35.97	0.285	.479	5.333	31	**

Null Hypothesis $H_o: B = 0$

NS - No significant difference at the 0.95 level.
* - Significantly different at the 0.95 level.
** - Significantly different at the 0.99 level.

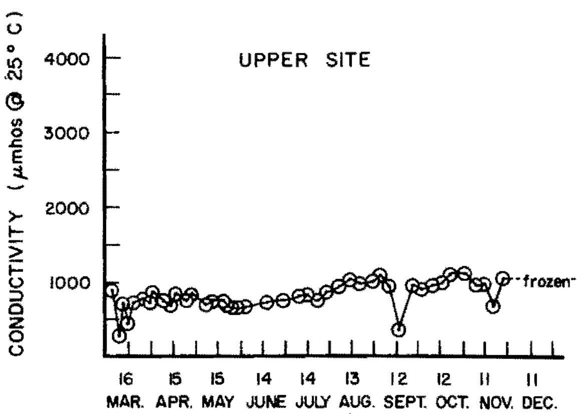


Figure 4.8. Conductivity at Coal Creek upper site.

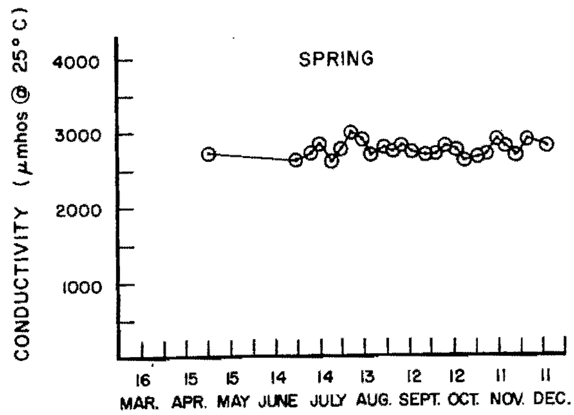


Figure 4.10. Coal Creek conductivity of the spring inflow.

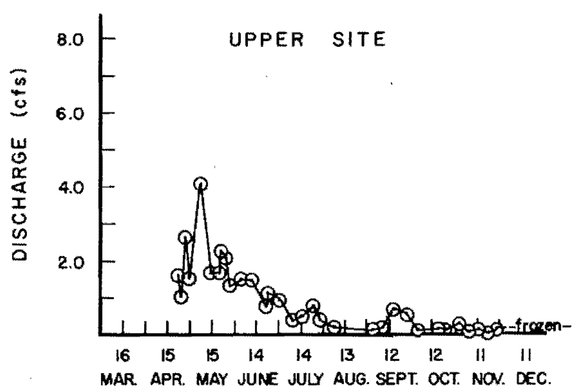


Figure 4.9. Flow at Coal Creek upper site.

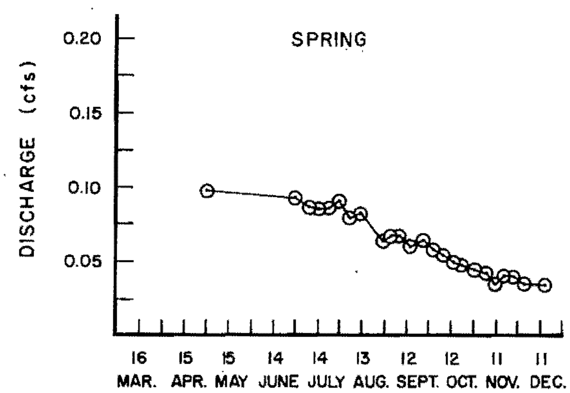


Figure 4.11. Coal Creek lateral inflow from the spring.

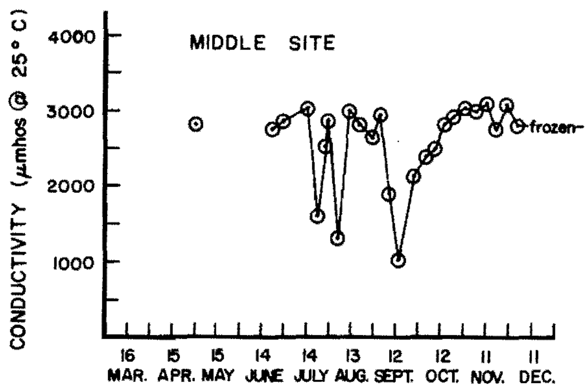


Figure 4.12. Coal Creek conductivity at the middle site.

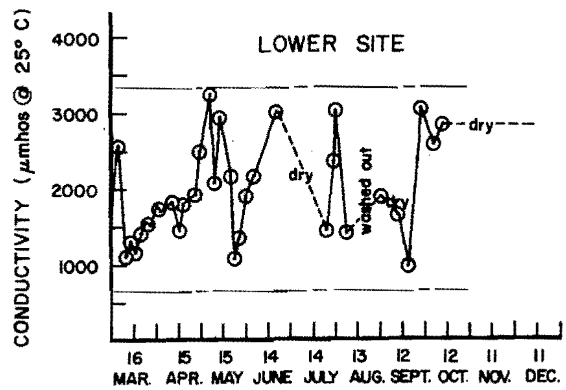


Figure 4.14. Coal Creek conductivity at the lower site.

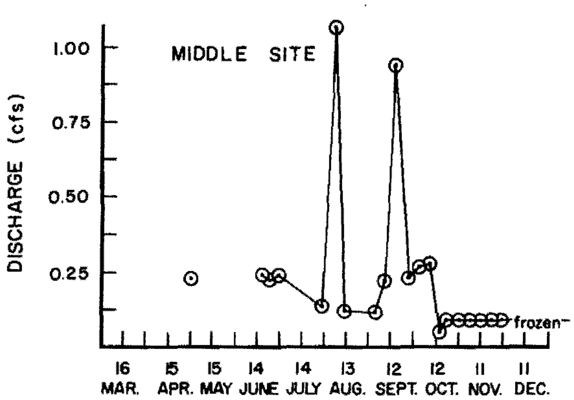


Figure 4.13. Coal Creek flow at the middle site.

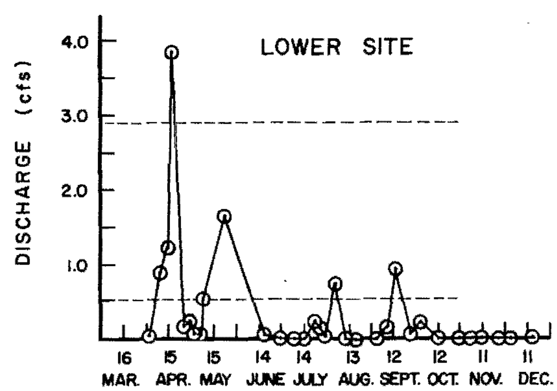


Figure 4.15. Coal Creek flow at the lower site.

Table 4.2. Observed chemical concentrations in Coal Creek.

Site		TDS mg/l	$SO_4^=$ mg/l	Cl^- mg/l	Ca^{++} mg/l	Mg^{++} mg/l	Na^+ mg/l
Upper	$\bar{X}$	513	153	13	51	26	79
	s	153	50	5	41	14	23
Spring	$\bar{X}$	2109	1176	9	184	76	360
	s	164	161	12	79	32	111
Middle	$\bar{X}$	1901	1137	22	184	69	315
	s	534	363	12	166	34	128
Lower	$\bar{X}$	1388	771	29	69	48	242
	s	598	397	12	54	29	153

$\bar{X}$ ≡ mean observed value
s ≡ standard deviation

conditions, little or no salt uptake was observed in the natural channels.

Sixty sediment samples were taken from channels throughout the Coal Creek study area, and conductivities were determined for their 1:1 saturation extracts. The objective was to determine if significant differences as salinity sources existed in materials taken from different depths, between banks and beds, and between main stem and tributary channels. The resulting chemical extract data are listed in Appendix C (Table C-3).

The predominant anion extracted was sulfate, with an observed mean concentration of 2245 mg/l and a standard deviation of 1955 mg/l. Much smaller concentrations of chloride and carbonates were found. The predominant cations were calcium, magnesium, and sodium with means of 299, 179, and 426 mg/l and standard deviations of 168, 217, and 587 mg/l, respectively. Relatively small concentrations of potassium were also found.

The means and standard deviations of the conductivities of the channel sediments segregated by the three-way classification are listed in Table 4.3. A student t-test was conducted to examine for significant differences among means assuming unequal variances (Lapin 1975). The results are listed in Table 4.4.

The only significant differences detected were in the bank materials and at depths greater than 10 cm between Coal Creek and its tributaries, and these were only valid at the 95 percent level. Significant salinity differences related to channel processes or geomorphology, even if they exist, are very difficult to detect because of extreme heterogeneity of Mancos Shale and Mancos Shale derived soils in the area (Ponce 1975).

To estimate the approximate magnitude of efflorescence in the natural channels, 1 cm deep soil samples were taken at the sites of

Table 4.3. Soil conductivities for beds and banks for Coal Creek locations.

Depth (cm)	Number of Observations	Average (mmhos @ 25°C)	Standard Deviation (mmhos @ 25°C)
Coal Creek Channel			
0-10	9	2.34	2.24
10-20	9	1.99	3.00
20-30	9	2.22	3.18
Coal Creek Banks			
0-10	21	3.30	2.60
10-20	21	2.66	2.13
20-30	21	2.92	2.53
Coal Creek Tributary Channels			
0-10	10	10.82	12.69
10-20	10	8.50	13.50
20-30	10	5.21	4.13
Coal Creek Tributary Banks			
0-10	20	6.13	5.87
10-20	20	5.01	3.55
20-30	20	5.37	4.15

the sediment samples of February 9 and July 8, 1977. From the efflorescence samples, the conductivity was measured, the TDS was estimated (Equation 4.2), and the efflorescent density in gm/m^2-cm was calculated.

$$TDS = 1.04\ (EC) - 551 \quad \ldots\ldots \quad (4.2)$$

in which

TDS = Total dissolved solids in mg/l
EC = Conductivity in mmhos/cm @ 25°C

The results are listed in Appendix C. The estimated effluorescent density ranged from a low of 18 gm/m^2-cm to a high of 9387 gm/m^2-cm measured in a Coal Creek tributary called Bitter Creek. This channel receives a small amount of interflow from the irrigated farmland (Figure 3.1). The mean effluorescent density was 1187 gm/m^2-cm with a standard deviation of 2230 gm/m^2-cm. The predominant efflorescent source is believed to be soil-water evaporation as described by Nakayama et al. (1973) and resulting in particularly heavy deposits on concave surfaces below saturated soil profiles and other locations where soil water comes to the surface.

Mineral dissolution from the Coal Creek channel material

Salt dissolution rates were measured in the laboratory by placing samples of unweathered Mancos Shale in quiescent distilled water and measuring conductivities of the solution periodically. For this purpose, six shale samples each were taken from four Coal Creek sites.

Table 4.4. Results of t-tests for significant differences among soil extract electrical conductivities of samples taken from Coal Creek and Coal Creek tributaries.

Comparison	t Statistic	df	Level of Significance
Depth Comparisons			
Coal Creek:			
Channel 0-10 vs. Channel 10-20	0.280	16	NS
Channel 0-10 vs. Channel 20-30	0.093	16	NS
Channel 10-20 vs. Channel 20-30	-0.158	16	NS
Bank 0-10 vs. Bank 10-20	0.873	40	NS
Bank 0-10 vs. Bank 20-30	0.480	40	NS
Bank 10-20 vs. Bank 20-30	-0.360	40	NS
Coal Creek Tributaries:			
Channel 0-10 vs. Channel 10-20	0.396	18	NS
Channel 0-10 vs. Channel 20-30	1.329	18	NS
Channel 10-20 vs. Channel 20-30	0.737	18	NS
Bank 0-10 vs. Bank 10-20	0.730	38	NS
Bank 0-10 vs. Bank 20-30	0.473	38	NS
Bank 10-20 vs. Bank 20-30	-0.377	38	NS
Main Stem-Tributary Channel Comparisons			
Coal Creek 0-10 vs. Trib. 0-10	-1.972	17	NS
Coal Creek 0-10 vs. Trib. 10-20	-1.348	17	NS
Coal Creek 0-10 vs. Trib. 20-30	-1.851	17	NS
Coal Creek 10-20 vs. Trib. 0-10	-2.032	17	NS
Coal Creek 10-20 vs. Trib. 10-20	-1.412	17	NS
Coal Creek 10-20 vs. Trib. 20-30	-1.924	17	NS
Coal Creek 20-30 vs. Trib. 0-10	-1.973	17	NS
Coal Creek 20-30 vs. Trib. 10-20	-1.358	17	NS
Coal Creek 20-30 vs. Trib. 20-30	-1.752	17	NS
Main Stem-Tributary Bank Comparisons			
Coal Creek 0-10 vs. Trib. Bank 0-10	-2.013	39	NS
Coal Creek 0-10 vs. Trib. Bank 10-20	-1.766	39	NS
Coal Creek 0-10 vs. Trib. Bank 20-30	-1.924	39	NS
Coal Creek 10-20 vs. Trib. Bank 0-10	-2.540	39	*
Coal Creek 10-20 vs. Trib. Bank 10-20	-2.585	39	*
Coal Creek 10-20 vs. Trib. Bank 20-30	-2.650	39	*
Coal Creek 20-30 vs. Trib. Bank 0-10	-2.293	39	*
Coal Creek 20-30 vs. Trib. Bank 10-20	-2.179	39	*
Coal Creek 20-30 vs. Trib. Bank 20-30	-2.295	39	*

Null Hypothesis H_o: $\mu_A = \mu_B$

NS - No significant difference between sample means at 0.95 level.
* - Significantly different at 0.95 level.

Three samples from each site were leached in an equal weight of distilled water for about 45 days. Then the solution was replaced with fresh distilled water, and the leaching continued for another 40 days. The conductivities measured are recorded in Appendix D, Table D.1. In the table, the actual conductivity measurements at the recorded temperature are converted to a 25°C base.

The other three samples from each site were leached for 7 days; they were then rinsed, dried at 103°C, and placed again in an equal weight of distilled water for 42 more days. Finally, they were rinsed and dried again and placed in a third solution for 37 days. These measured conductivities are recorded in Appendix D, Table D.2.

As one would expect, dissolution rates were rapid at first, declined with time, and eventually approached zero (accumulated conductivity ceased to increase). About 80 percent of the total dissolution occurred during the first 3 days. Also, as one can see from Table D.1, the dissolution rate in the second batch of distilled water was only one third to one half that in the first. Samples that were rinsed and dried between leachings had faster dissolution rates than did samples that were merely placed back into fresh distilled water.

Several tests were made for the statistical significance of differences in dissolution rates. The first was to determine whether the differences in total accumulated conductivity over approximately the first

45 days between samples left in the same solution the entire time and samples rinsed, dried, and placed in a second batch of distilled water were significant. Data from Table D.1 after 37 days (12/7/76) and Table D.2 after 48 days (12/20/76) as shown in Table 4.5 were used. The shorter period was used for the first block of data because the accumulated conductivity had stabilized at an apparent saturation level by this time. For the second block of data, the conductivities accumulated before and after rinsing and drying were assumed additive.

The test was first made with a two-way analysis of variance (Neter and Wasserman 1974) with the results in Table 4.6. For the two F-tests, the null hypotheses were defined as 1) the four shale sources do not have the same dissolution rates and 2) the leaching in one batch of water does not have the same dissolution rate as rinsing, drying, and placing in a second batch of water. The results show significant differences among the shales and, given that difference, significant differences between treatments. The data were also examined by a model presented by Hicks (1973) that adds a third test, one for an interactive effect between source and treatment. The interactive effect was also found to be significant. These results are generally the same as those previously found by Burges (1974).

The suggested physical explanation is that rinsing and drying disrupts an inhibiting physical or chemical boundary layer and thereby increases subsequent mineral dissolution. One could reasonably expect the same effect in nature as shales are dried and exposed to solar radiation between runoff events.

The next test was to determine whether the difference in total accumulated salt dissolution continued to be significant through a second cycle. The data in Table 4.7 show total dissolution during the 85-day leaching period. The two-way analysis of variance produced the results in Table 4.8. Again, the statistical test shows

Table 4.5. Effect of rinsing and drying on accumulated conductivity.

	45-Day Cumulative Conductivities (μmhos/cm @ 25°C) Shale Source Site*			
	1	2	3	4
Samples kept in same solution (37-day)	1.387	0.873	0.540	1.048
	1.594	1.070	0.497	1.081
	1.545	1.033	0.497	1.060
Samples rinsed, dried and placed in fresh distilled water on seventh day (48-day)	2.284	1.394	0.829	1.713
	2.269	1.548	0.868	1.311
	2.297	1.516	0.808	1.560

Shale Source Sites:
1. Experimental Channel
2. Coal Creek Above Spring
3. Coal Creek Lower Site
4. Coal Creek Middle Site

Table 4.6. Analysis of variance for significance of the effect of rinsing and drying.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squared	F	Level of Significance
Shale Source	4.48495	3	1.495	18.457	95 percent
Treatment	1.58209	1	1.582	19.531	95 percent
Error	0.34396	3	0.081		
Total	6.37	7			

Null Hypothesis H_o: $\mu_1 = \mu_2 = \mu_3 = \mu_4$;

$\tau_1 = \tau_2$

Table 4.7. Total accumulated conductivity including additional treatment.

	85-day Cumulative Conductivities (μmhos/cm @ 25°C) Shale Source Site*			
	1	2	3	4
Rinsed samples	1.936	1.218	0.812	1.544
	2.142	1.407	0.759	1.614
	2.091	1.356	0.747	1.552
Rinsed and dried samples	3.009	2.009	1.115	2.214
	2.907	2.253	1.158	1.851
	3.037	2.151	1.070	2.198

1. Experimental Channel
2. Coal Creek Above Spring
3. Coal Creek Lower Site
4. Coal Creek Middle Site

Table 4.8. Analysis of variance for significance of the effect of additional rinsing and drying.

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squared	F	Level of Significance
Shale Source	7.501	3	2.5	15.030	95 percent
Treatment	2.531	1	2.531	15.216	95 percent
Error	0.499	3	0.166		
Total	10.531	7			

Null Hypothesis H_o: $\mu_1 = \mu_2 = \mu_3 = \mu_4$;

$\tau_1 = \tau_2$

significant differences among shales and a continuing significant difference between treatments on the seventh day.

The differences were probed once more by testing dissolution amounts during the second 40-day treatment period. The results in Table 4.8 cover the entire 85-day period and thus, according to the results reported in Table 4.6, would be significant if a constant dissolution were added during the second 40-day period. Therefore, Hicks' (1973) model was used to test for significant differences among shales, between treatments, and in interaction between the two. Again, all three differences were found significant.

The results of these tests have important implications. Dissolution rates vary significantly among shales and with the history of wetting and drying as the material moves downstream. The many shale sources and histories will make it very difficult to estimate dissolution rates in a given stream. Also, the tendency of wetting and drying cycles to increase dissolution would cause more of the salts in the bed material of ephemeral channels to be leached out before the bed material reaches a larger stream. Material directly entering a perennial stream may move through the system with much more of its salt content in tact. These materials may continue as an important salt source downstream on the Colorado River for years.

Time rates of dissolution

Whitmore (1976) found that when salt dissolution rates are plotted against the square root of time a broken curve of the sort illustrated by Figure 4.16 results. Accordingly, an attempt was made to fit the dissolution data with a square root model of the form:

$$C = K_1 T^{0.5} . . . . (4.3)$$

in which

C = The specific conductance in μmhos, at time T
T = Time in minutes
K_1 = A dissolution

In order to determine the effect of grain size on dissolution rates, accumulated conductivities were also measured in the laboratory for shale samples separated by grain size with the results shown in Table D.4. Equation 4.3 fit the data with a single constant K_1 rather than with the breakpoint shown in Figure 4.16. Eighty percent of the 72-hour conductivity was obtained after a mean of 9.4 hours, with a standard deviation of 7.1 hours, as compared to the few minutes found by Whitmore (1976) for Mancos soil. The advanced weathering state of the channel material used by Whitmore probably accounts for the rapid dissolution that he observed.

The results of the student t-test analysis for differences by grain size of the 30-second and 72-hour conductivity values are presented in Table 4.9. The significant increase in 30-second dissolution for smaller grain sizes is evidence that the initial rate of salt dissolution increases with partial surface area.

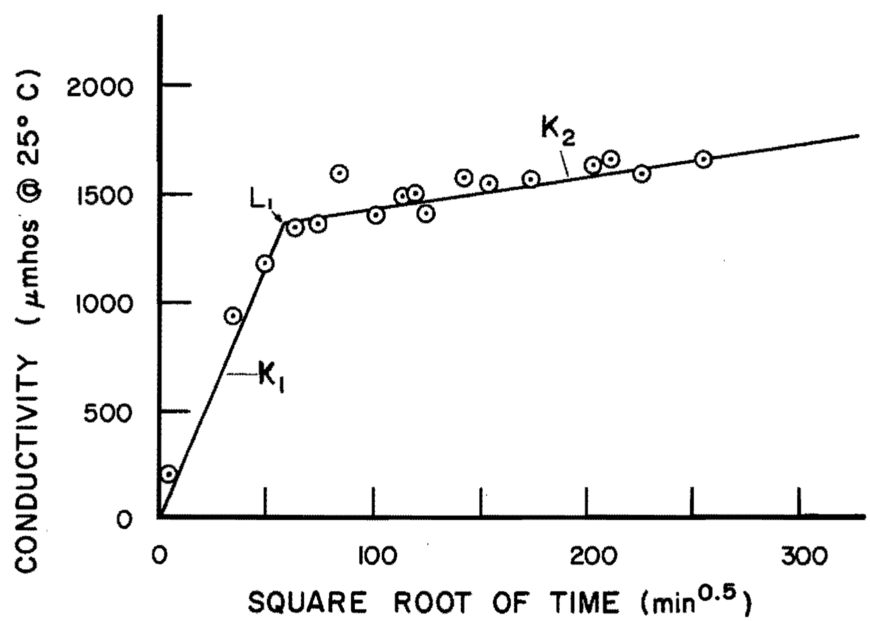


Figure 4.16. Accumulated conductivity from laboratory salt dissolution.

Table 4.9. Comparison of mineral dissolution rates with time and grain size.

Comparison	t Statistic	df	Level of Significance
30-second comparisons			
#4 vs. #10	-0.195	6	NS
#4 vs. #20	-2.856	6	*
#4 vs. #60	-6.173	6	**
#10 vs. #20	-3.040	6	*
#10 vs. #60	-6.350	6	**
#20 vs. #60	-4.132	6	**
72-hour comparisons			
#4 vs. #10	0.275	6	NS
#4 vs. #20	-1.437	6	NS
#4 vs. #60	-1.804	6	NS
#10 vs. #20	-1.770	6	NS
#10 vs. #60	-1.925	6	NS
#20 vs. #60	-1.172	6	NS

Null Hypothesis H_o: $\mu_A = \mu_B$

NS - No significant difference between sample means at the 0.95 level.

* - Significantly different at the 0.95 level.

** - Significantly different at the 0.99 level.

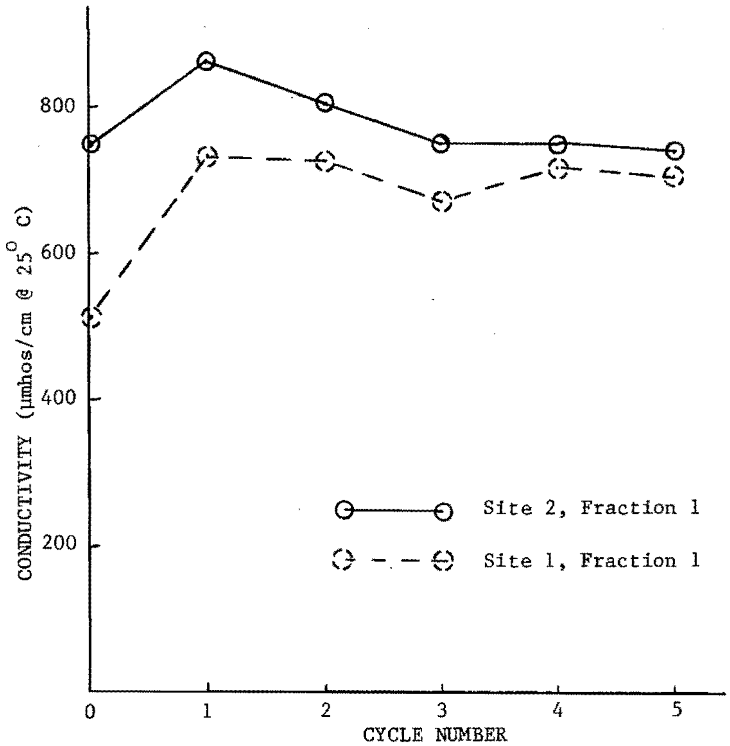


Figure 4.17. Illustrative effect of wetting and drying cycles on conductivity.

A test was designed to estimate the effect of the number of wet/dry cycles on salt release rates for various shale size fractions. Shale samples from the four sites were crushed and separated into four size fractions, for a total of 16 individual samples. From each sample, 50 grams of soil were saturated with 100 ml of distilled water and placed within a Brinkmann Roto-evaporator (rotovap) and water bath. By this method, numerous wet/dry cycles are possible within a 1-day period. Because salts are removed in a 5 ml aliquot, a 5 percent adjustment was assumed to be necessary after each successive wet/dry cycle. The conductivity values were linearly adjusted and corrected to 25°C. The results are presented in Appendix C (Table C.2). The test was terminated after 10 samples were evaluated.

Figure 4.17 illustrates the results. An increase in dissolution causing greater solution conductivity after the first drying cycle was observed for all of the samples. The increase ranged from 5 percent to 43 percent with a mean of 21 percent and standard deviation of 12 percent. Following the second drying cycle, only three of the 10 samples had an increase in conductivity. The variation ranged from a minus 8 percent to a positive 10 percent, with a mean of a minus 2 percent and a standard deviation of 6 percent. Further wet/dry cycles generally brought additional conductivity declines.

The unexpected decline in conductivity after just one cycle may be due to experimental error or to characteristics of the rotovap. During the drying, vigorous boiling of the slurry occurred, and the larger aggregates were rapidly eroded. Thus, it is possible that the mineral dissolution was accelerated to the point that most of the salts were released from the shale samples after only one cycle. Variation in the conductivity of the following cycles might have been caused by irregular mass loss during drying. Solids splashed into the condensor unit during evaporation, and no adjustment was made for their mass.

The rate of salt release from a shale surface would be expected to be rapid at first and then to decline as the supply of surface salt diminished, leaving the much slower release of salts entrained beneath the surface of the relatively impermeable shale. Under steady-state flow conditions, the salts would be released by diffusion-controlled dissolution from the submerged shale. Oven-drying of the sample (sun drying in the field) increases the surface area of the shale as water of hydration is lost, fracturing develops, and diffusion inhibiting boundary layers are disrupted.

Macrochannel induced streamflow studies

One problem in measuring salt pickup from various salinity sources is that of separating salt pickup from within the surface channels from salt brought into the channel by overland flows. In order to collect data for this separation, a small ephemeral channel was supplied with water from an irrigation ditch, a situation where no overland flow occurs. The instrumentation is described in Chapter III. The experimental channel is referred to as the macrochannel (Figure 3.3), and the results are listed in Appendix C (Figures C.3, C.4, and C.5 and Tables C.7 and C.8).

Flow was induced on August 26 and September 9, 1976, for 7 and 4 hours respectively. The mean flow was 0.1 cfs but amounts were highly variable (Appendix C, Figures C.4 and C.5). Flow was monitored at four flumes approximately 400 feet apart (Figure 3.3). A typical TDS curve of salt concentration as a function of time after the induced flow began at the most upstream flume is illustrated in Figure 4.18. TDS was estimated by the following relationship previously derived for Coal Creek data.

$$TDS = 0.746\ C \quad \ldots\ldots\ldots\ldots \quad (4.4)$$

in which

TDS = Total dissolved solids (mg/l)
C = Conductivity (μmhos/cm @ 25°C)

The salt concentration of the induced flow was initially high, as would be expected, and then declined as the more exposed or highly soluble salts in the channel dissolved.

A plot of accumulated salt load versus accumulated flow (Figure 4.19) at the three downstream flumes supports linear loading during the first few hundred cubic-feet of flow. Such an initial linear response was also reported by White (1977a) in comparing accumulated salt load versus accumulated sediment. The later decrease in the slope of each curve is produced by a falling rate of salt pickup after the more exposed salts have been dissolved from the channel sections.

Plots for the two induced flow tests of accumulated salt load versus the square root of time (Figures 4.20 and 4.21) indicate that the data plot as straight lines with high correlation (Table 4.10). The salt loading response is similar to that observed in the laboratory jar tests of the Coal Creek channel sediments. The Coal Creek sediment analysis showed a break in the square root linear relationship at about 60 hours (65 $min^{0.5}$ on Figure 4.16). The curves of Figures 4.20 for August 26 and 4.21 for September 9 cover only 6 hours and thus are entirely in the initial steep section of Figure 4.16.

Assuming a uniform channel geometry, an average salt loading rate per unit of channel length may be calculated for the mean wetted perimeter (Table 4.11). Figure 4.19 shows that the rate of release declines downstream. Some differences in the rate of salt pickup between channel sections can be explained on the basis of nonuniformities in the salinity potential of the streambed. How-

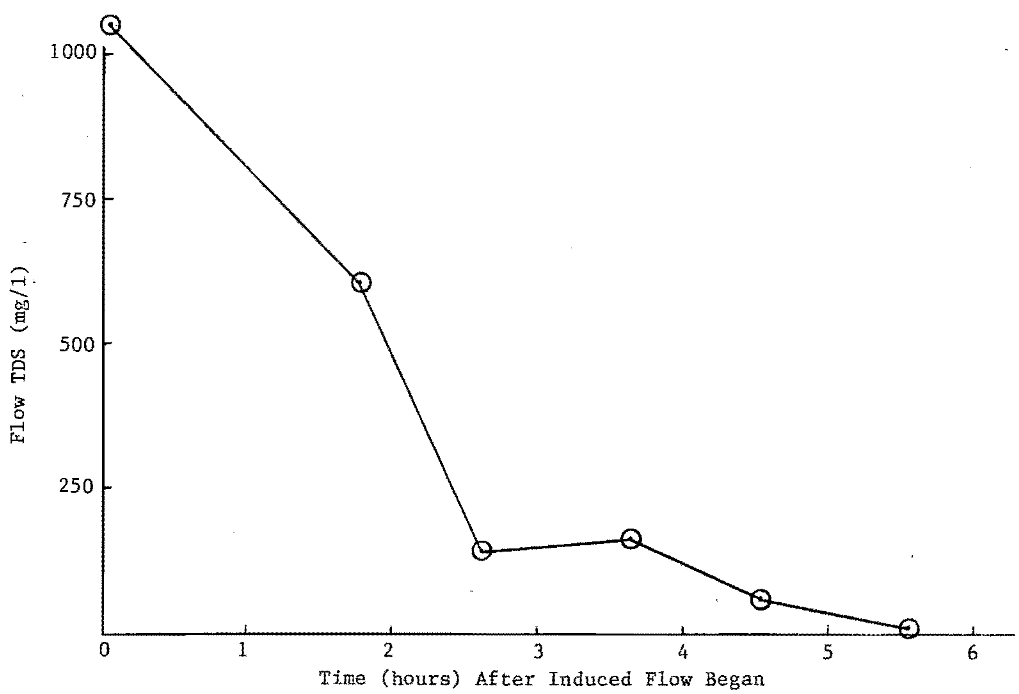


Figure 4.18. Illustrative macrochannel salt concentration response.

Table 4.10. Linear regression of accumulated salt load versus the square-root of time.

Flume #	Date	Acc. Salt Load gms/min$^{0.5}$	r^2
2	8/26/76	255.02	0.995
3	8/26/76	371.12	0.999
4	8/26/76	487.36	0.999
2	9/9/76	163.37	0.998
3	9/9/76	203.36	0.991
4	9/9/76	394.22	0.998

Table 4.11. Macrochannel salt loading per unit channel length.

	Salt Loading Rates grams/feet-min$^{0.5}$	
Flume #	Run #1	Run #2
2	0.64	0.41
3	0.46	0.25
4	0.41	0.33

ever, the general declining downstream trend might be produced by 1) a loss of channel flow by seepage (and thus a reduced wetted perimeter), and 2) an associated reduction in the sediment carrying capacity of the flow.

Sediment bedload samples (500 grams) were taken during both occasions of induced flow. Some of the sediment samples were air dried for 90 days before being placed in distilled water, and the remainder were directly placed in 500 ml of distilled water. For each sample, a the rate of salt released as a function of time was examined. The results are presented in Appendix D (Table D.4). Figure 4.22 presents illustrative sediment dissolution responses, one for a dry sample and the other for a wet sample, each adjusted to 500 grams of soil. Both dissolution rates are linear with respect to the square-root of time, and both curves break at about 11 hours (80 min$^{0.5}$). The test results also indicated that about 11.5 days from the beginning the weight of the released salt reached a maximum of approximately 0.16 percent of the sediment weight.

The data plotted in Figure 4.22 confirm a breakpoint in the dissolution rate of the sort presented in Figure 4.16. From the

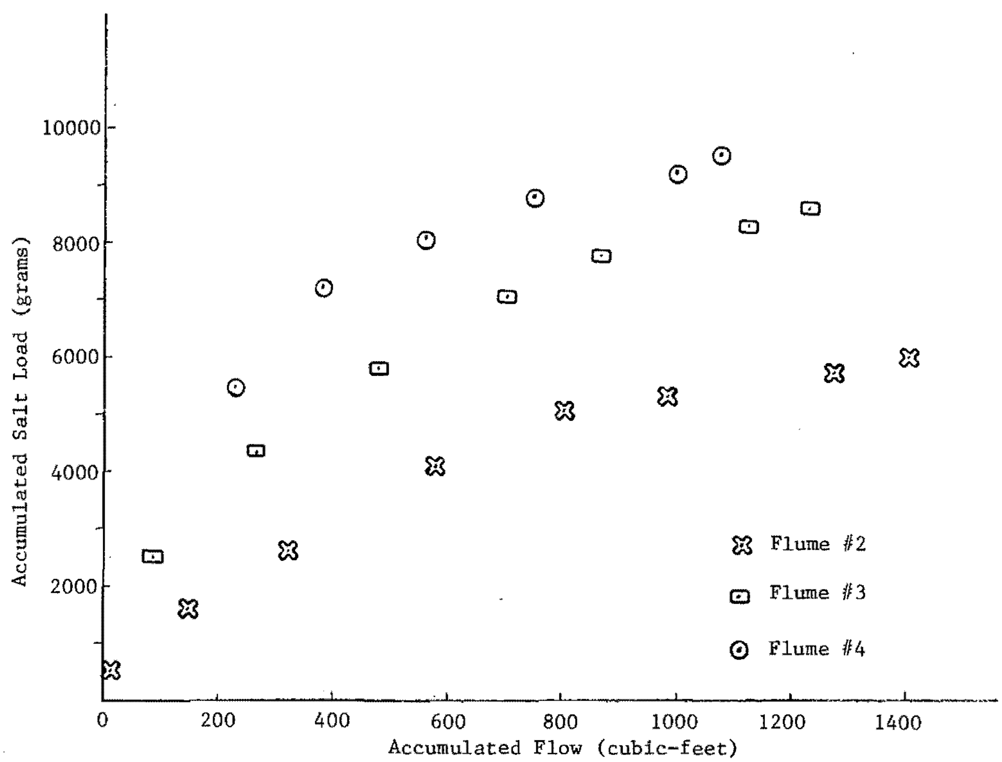


Figure 4.19. Accumulated salt load versus accumulated flow at flumes 2, 3, and 4 of the macrochannel, August 26, 1976.

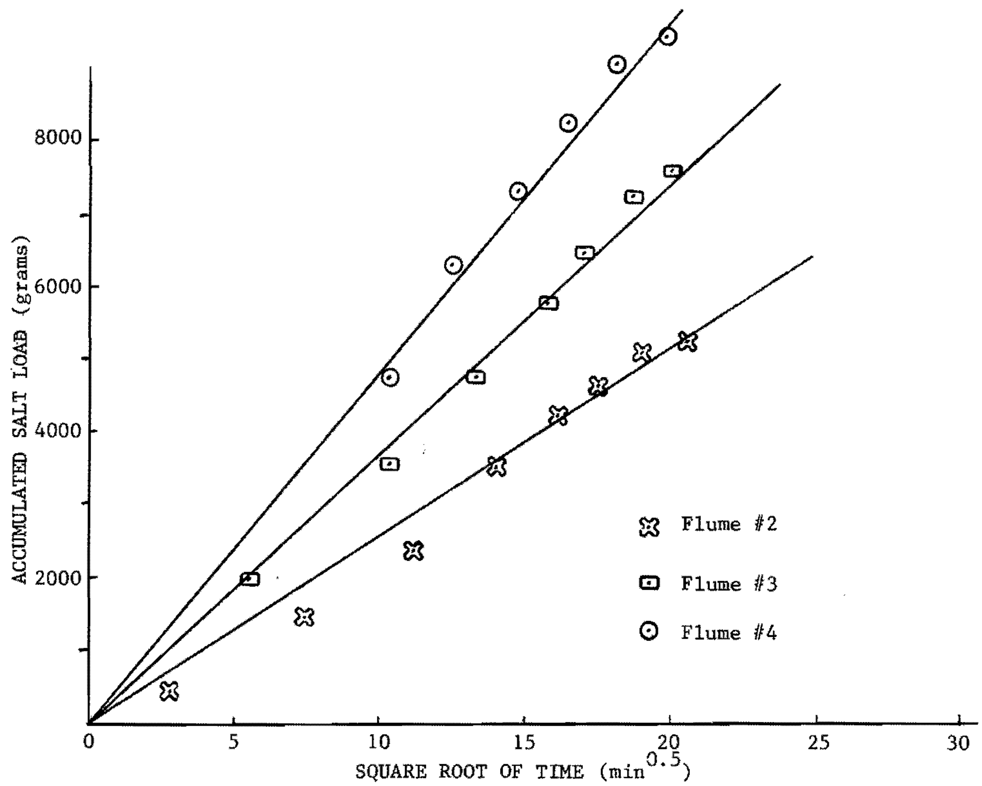


Figure 4.20. Macrochannel salt load versus the square-root of time (8/26/76).

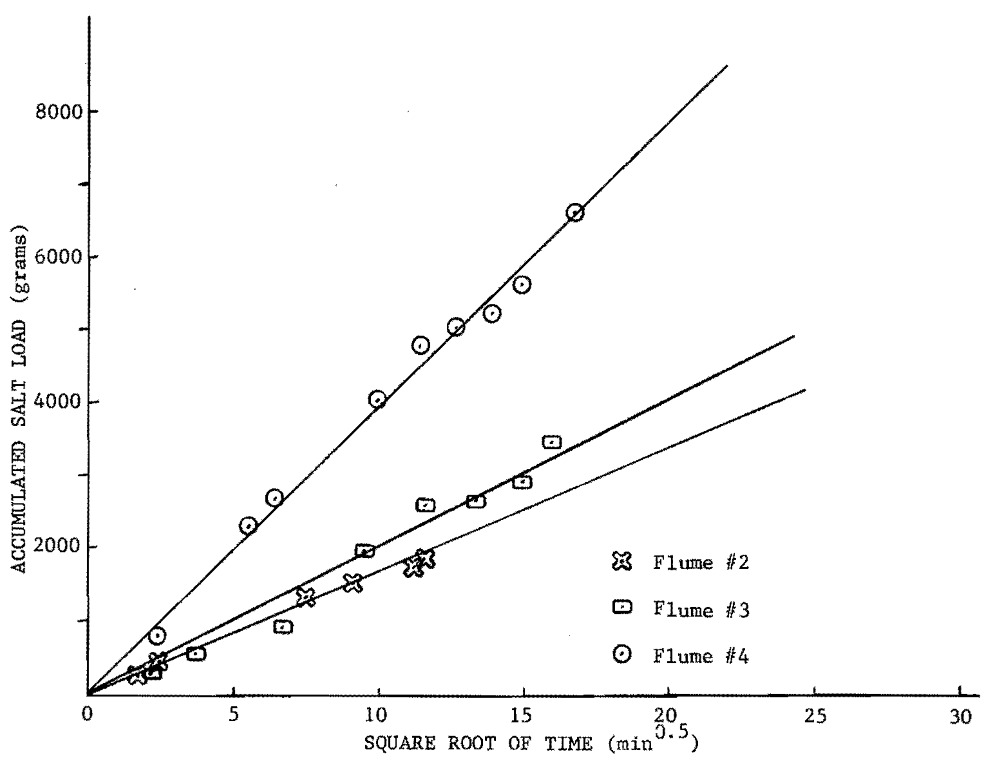


Figure 4.21. Macrochannel salt load versus the square-root of time (9/9/76).

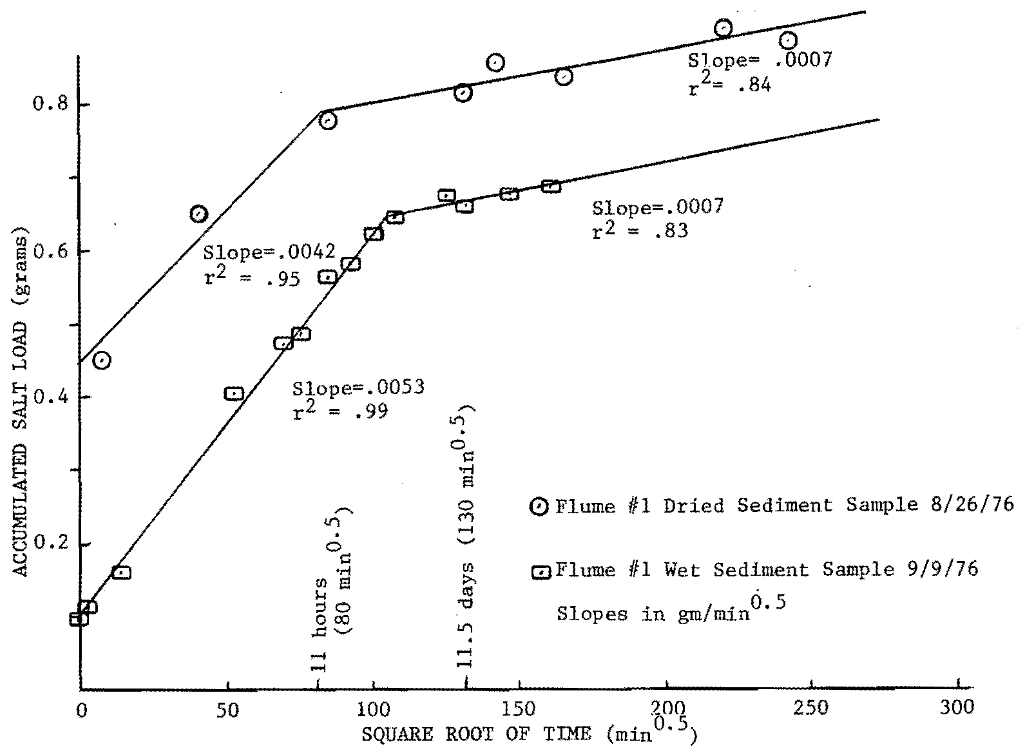


Figure 4.22. Salt dissolution from macrochannel bedload material.

replications in the four samples in each set, the two slopes and the breakpoint time were calculated. The results are listed in Table 4.12. Comparisons were made among sediment samples of the total salt release at 1) the end of the steep portion of the curve (Figure 4.22), and 2) at 11.5 days. A t-statistic was used to test the null hypothesis that the accumulated conductivity means were equivalent with the results listed in Table 4.13. Drying the sediment significantly increased the salt released during the steep portion of the curve. However, after 11.5 days there was no significant difference in the cumulative salt release for the two sample treatments.

Soil salinity sensors were installed in the macrochannel on August 15, 1976, and monitored weekly (Figure 3.3). The sensors had been saturated with a 4000-μmhos/cm (at 25°C) solution of calcium and sodium chloride. The manufacturer of the sensors, Soil Moisture Equipment, Inc. (1976), recommend the following operating ranges for the sensors:

1. A soil moisture tension range of from 1 to 15 bars.

2. A conductivity range of from 500 to 30,000 μmhos/cm at 25°C.

Table 4.12. Mean salt dissolution rates for macrochannel sediments.

	Estimated Salt @ Time Breakpoint	Estimated Salt @ Time $\sqrt{t}$ = 125	K_1 gms/$min^{0.5}$	L_1 $min^{0.5}$	K_2 gms/$min^{0.5}$
Wet Sediment Samples 8/26/76					
$\bar{X}$	0.094	0.672	0.00462	*	*
S	0.081	0.236	0.00226		
Dried Sediment Samples 8/26/76					
$\bar{X}$	0.341	0.705	0.00384	83.38	0.00107
S	0.071	0.133	0.00120	1.00	0.00062
Wet Sediment Samples 9/9/76					
$\bar{X}$	0.070	0.740	0.00670	92.41	0.00156
S	0.023	0.176	0.00156	10.36	0.00110

4 replications for each group of samples
K_1, L_1, K_2 defined on Figure 4.16
*No break observed in curve

Table 4.13. Analysis of salt dissolution rates for channel receiving no overland flow.

Comparison	t Statistic	Degrees of Freedom	Level of Significance
Estimated salt @ breakpoint			
Wet 8/26/76 to Dried 8/26/76	-4.59	6	95 percent
Wet 8/26/76 to Wet 9/9/76	0.570	6	NS
Dried 8/26/76 to Wet 9/9/76	7.262	6	95 percent
Estimated salt @ $\sqrt{t} = 125$			
Wet 8/26/76 to Dried 8/26/76	-0.24	6	NS
Wet 8/26/76 to Wet 9/9/76	-0.46	6	NS
Dried 8/26/76 to Wet 9/9/76	0.32	6	NS

Null Hypothesis H_o: $\mu_A = \mu_B$

The collected data are listed in Appendix C (Table C.9). Illustrative patterns of observed conductivity at four depths are shown on Figure 4.23 for the upper site (Figure 3.3). Conductivity slowly dropped with time from the initial 4000 μmhos/cm at 25°C to less than 500 μmhos/cm at 25°C at 3 and 18 cm depths, and to less than 2000 μmhos/cm at 25°C at the 29 and 41 cm depths, respectively, a general trend toward higher conductivity at greater depth.

Soil moisture tensions in the soil matrix were not monitored during these tests, and thus it is possible that the capacity of the sensors might have been exceeded. Under these conditions, a drop in the soil moisture content below the saturation level would reduce the observed conductivity.

The relatively slow changes in conductivity indicate slow rates of salinity transport through the channel bed material. This observation was confirmed by permeability studies at four sites adjacent to Coal Creek. Four test holes were drilled to a depth of 1 meter at a horizontal distance of 1 meter from the surface flow in Coal Creek. For each of the sites, no inflow to the holes was observed during the first 24 hours after drilling.

Discussion and Analysis of Results

Although approximately 60 percent of the salt load passing Woodside originates in the mountainous areas of the Price River Basin, the joint effect of consumptive use reducing flows and salt loading on the valley floor multiplies salinity concentrations by over ten (Figure 4.5). Within the valley, three tributaries (Drunkards Wash, Desert Lake Wash, and Desert Seep Wash) are particularly high salt contributors to the Price River. The three streams contribute average daily salt loads of 518, 416, and 423 pounds per square mile of drainage area, respectively. Each stream drains irrigated farm land.

Surveys of the valley floor suggested that subsurface inflows to the Price River account for a large portion of the total salt load originating in the valley. In contrast, longitudinal salt pickup from the mineral weathering of bed sediments in natural perennial channels was low in all the observed cases, irrespective of the salt concentration of the flowing water in the channel.

From these findings, it is believed that the primary source of salinity in natural perennial streams with high salt concentrations is saline groundwater inflow. TDS values of 9000 mg/l and higher were observed in the field, and salt contents of some minerals may approach saturation. Where saturation occurs, TDS loadings are no longer additive, and salts are deposited, probably to be picked up later during high flow periods. Ion distributions would have to be considered in modeling salinity transport.

Overland flow from storms occurred predominantly during the spring and summer months. Surface runoff was rapid, turbulent, and of short duration with little depression storage observed. A salinity profile of overland flow was not obtained.

Within the main channel of Coal Creek, the longitudinal pickup of salt was low. Salt loading by groundwater inflow tended to be constant. Indigenous salts in the channel material of Coal Creek were heterogeneous with respect to mineral type and concentration. Efflorescence density within the Coal Creek subbasin channel beds was also found to be highly variable, with observed densities ranging as high as 9000 gm/m^2-cm. The source of the efflorescence seemed to be primarily evaporation of saline subsurface inflows to the channel.

Laboratory jar tests on the Coal Creek channel sediments and shales indicated that mineral dissolution rates declined exponentially with time. This observation meshes with the observed low longitudinal salt uptake in perennial streams. Drying or turbulent mixing of the samples generally increased the rate of mineral dissolution.

Channel salt pickup studies were conducted by supplying a small ephemeral tributary within the Coal Creek drainage with water from an irrigation ditch. The salinity pickup was found to decrease exponentially with time in this channel reach with low

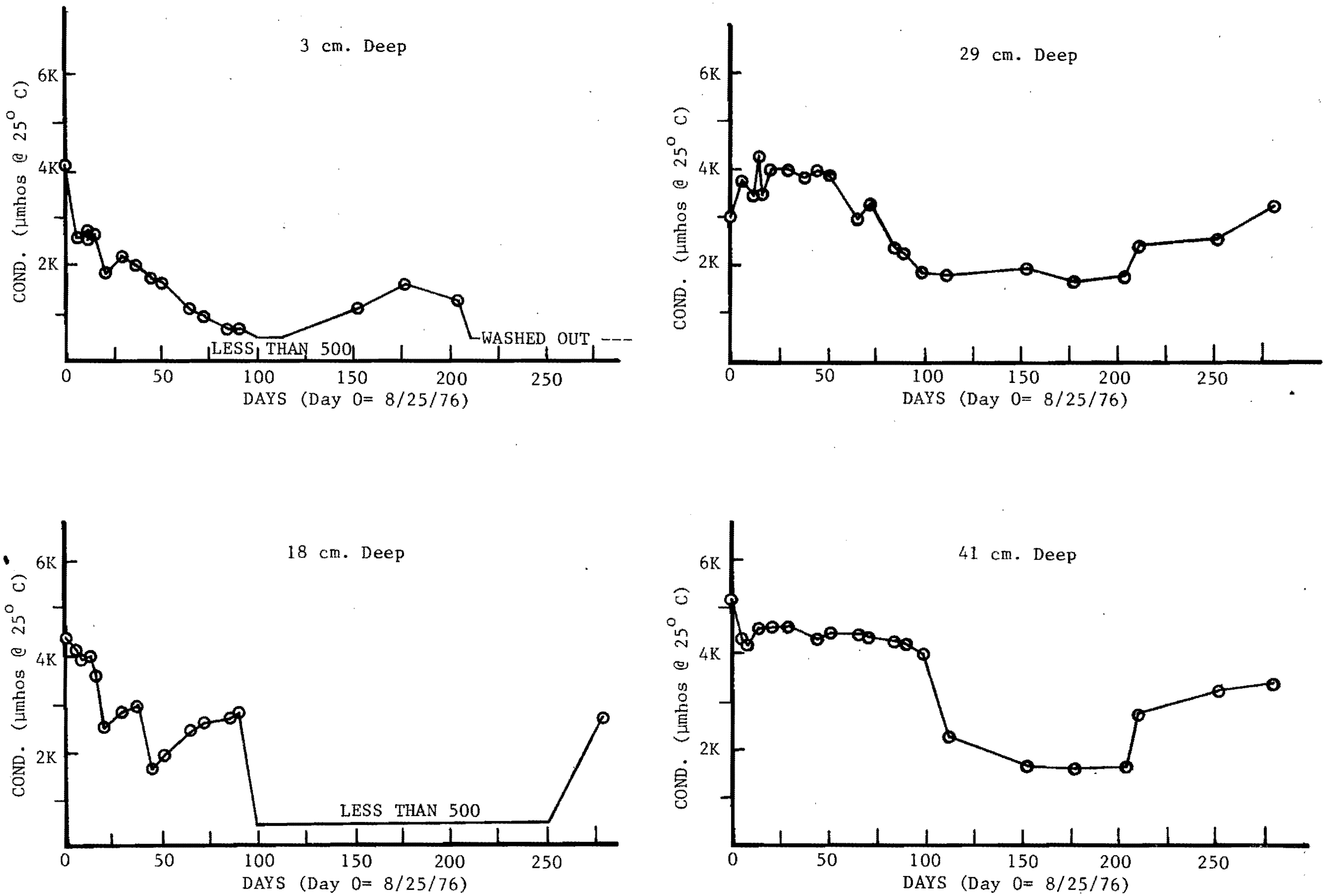


Figure 4.23. Typical salinity sensor response curves.

seepage losses. At a particular time, the rate of salt loading decreased in the downstream direction. From these trends, the accumulated salt load per unit area from the fixed and suspended channel bed materials may be described by Equation 4.3. Multiplication by the bed area to estimate the total salt load gives:

$$C = K_1 \cdot T \cdot L \cdot WP \quad (4.5)$$

in which

C = The accumulated salt load in grams at distance, L, from the point of flow introduction at time, T
T = Time in minutes from the beginning of flow
k_1 = The salt loading coefficient ($gm/min^{0.5}$-ft^2)
L = channel length in feet
WP = Wetted perimeter in feet

In a concurrent study, flows were induced in six small channels in the Price River Valley (White 1977b) on three separate occasions. The channels were monitored at points 10, 25, 50, and 100 feet downstream from where the flow was introduced. The flow was held steady, and inflow, outflow, and wetted perimeter were measured. By least squares regression, a loading coefficient (K_1 in Equations 4.3 and 4.5) was calculated for each induced flow. At the 100-foot position, all of the correlation coefficients exceed 0.98.

A plot of the regression estimated rates of dissolution per unit of wetted area for channel 2-1 (White 1977b), located in the Coal Creek subbasin, is illustrated in Figure 4.24. The dissolution rates after the first 25 feet decline approximately linearly with channel length. The decline supports the observations of the Coal Creek macrochannel study. This trend likely reflects a reduction in channel sediments pickup as the sediment carrying capacity of the flow is approached.

However, not all channels responded with a negative slope (Figure 4.25). The dissolution rates in channel 1-2, located outside of the Coal Creek drainage, increased after the flow passed the 50-foot point, probably due to heterogeneity in the salinity of the channel materials. Dissolution rate changes should be expected where flows cross onto a different bed material.

An average rate of salt loading (K_1) for the Coal Creek study area was estimated by averaging the observed loading rates from channels within the area. The result was an average loading rate of 2.51 $gms/min^{0.5}$ per square foot of channel, with a standard deviation of 3.17 $gm/min^{0.5}$ per square-foot of channel, indicating a great deal of variation among locations.

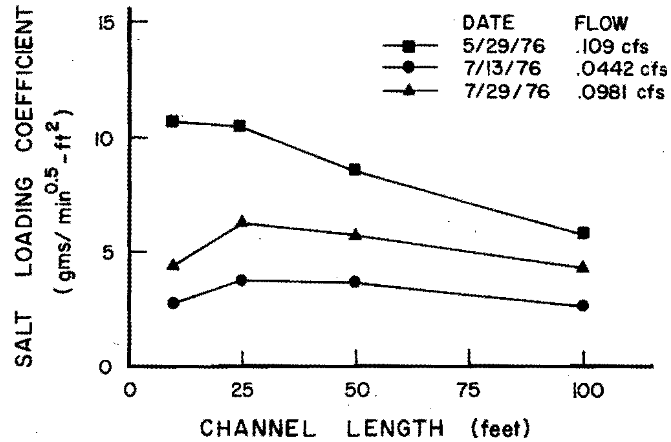


Figure 4.24. Channel 2-1 salt load coefficient.

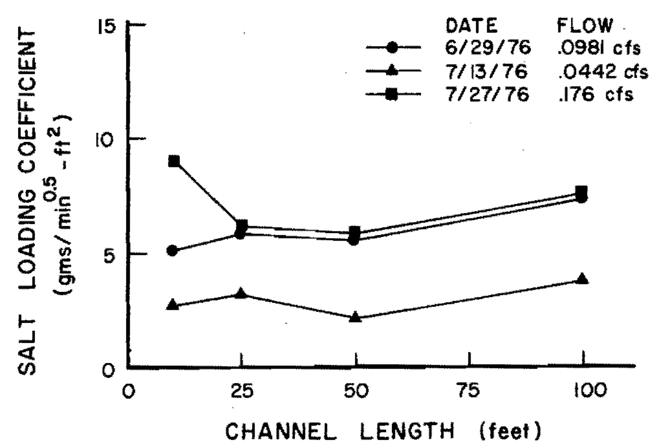


Figure 4.25. Channel 1-2 salt loading coefficient.

CHAPTER V

THE HYDROSALINITY MODEL

Introduction

The stated study objectives included developing a hydrosalinity model of salt loading and transport, calibrating the model to Price River tributary conditions, and running the calibrated model to compare salt loadings from various sources quantitatively. This chapter presents the model development.

Modeling strategy

Numerous watershed hydrologic/salinity (hydrosalinity) models have been developed. They vary in resolution from Durum's (1953) hyperbolic relationship to Narasimhan's (1975) bio-chemical salinity model. The better models have successfully represented perennial streams with time-averaged results. The modeling of ephemeral streams with only short periods of flow has, however, had little success (e.g., Pionke and Nicks 1970). This study builds a first generation mathematical model to estimate salinity concentration in an ephemeral stream traversing Mancos Shale wildlands.

The procedure (Figure 5.1) for development and application of a simulation model, described by Riley et al. (1974), was attempted in this study. While data limitations prevented adequate model verification, the Coal Creek model is considered capable of providing a reasonable estimate of the relative salt levels in that stream from 1) overland flows, and 2) channel flows.

System identification

The model objective was better quantitative understanding of the salt loading of the Price River. The relevant system incorporates the processes which bring water and salt into the channel. These can be selected from the representation of the runoff phase of the hydrologic cycle on Figure 5.2. The boxes represent catchment storages, and the solid lines represent physical processes whereby water moves from one storage to another.

Salts are moved by water, and thus most of the solid lines representing water movement are associated with salt movement represented by a dashed line. The exceptions are storages and movements in the atmosphere where salt contents are low enough to be neglected for accomplishing the objectives of this model.

The conceptual hydrosalinity model developed by adding the dashed lines to Figure 5.2 is expanded into a mathematical model by equations portraying the physical processes of water and salt movement from box to box and box storage capacities. Because this study focuses on salt pickup by surface runoff processes (overland and channel flows), the total system depicted by Figure 5.2 can be simplified to consider only flows overland and in surface channels. For application to the Coal Creek study unit, further simplifications were possible because salt transport occurs mainly during surface runoff events and little or no surface runoff occurs during the snowmelt period.

Furthermore, because the major salt loading is associated with surface runoff producing events of short duration, it was possible to simplify the system by considering all long-term, time dependent processes to have negligible salt loading effects.

The above focus and assumptions were used to simplify the hydrosalinity flow diagram to Figure 5.3. The remainder of this chapter explains the formulation of a hydrosalinity model covering the storages and processes shown in that flow diagram with equations developed from the data on salt pickup processes presented in the previous chapter.

As a strategy for beginning, the model was constructed to replicate individual storm events between April 1 and October 31. Most natural salt movement occurs during isolated periods of storm runoff during the otherwise long dry summer. Continuous and winter modeling might enhance model performance in estimating antecedent moisture for predicting storm runoff or percolation through the ground seeping into the stream through its banks, but such refinements can be added once the basic structure of Figure 5.3 is implemented.

Hydrology Component

Precipitation (RAIN)

Summer storm events on the Price River Basin are few, short, and localized. Historical precipitation series have not been measured in the watersheds of primary interest for this study, are generally measured on too coarse a time grid, and are too short to cover the range of storm pat-

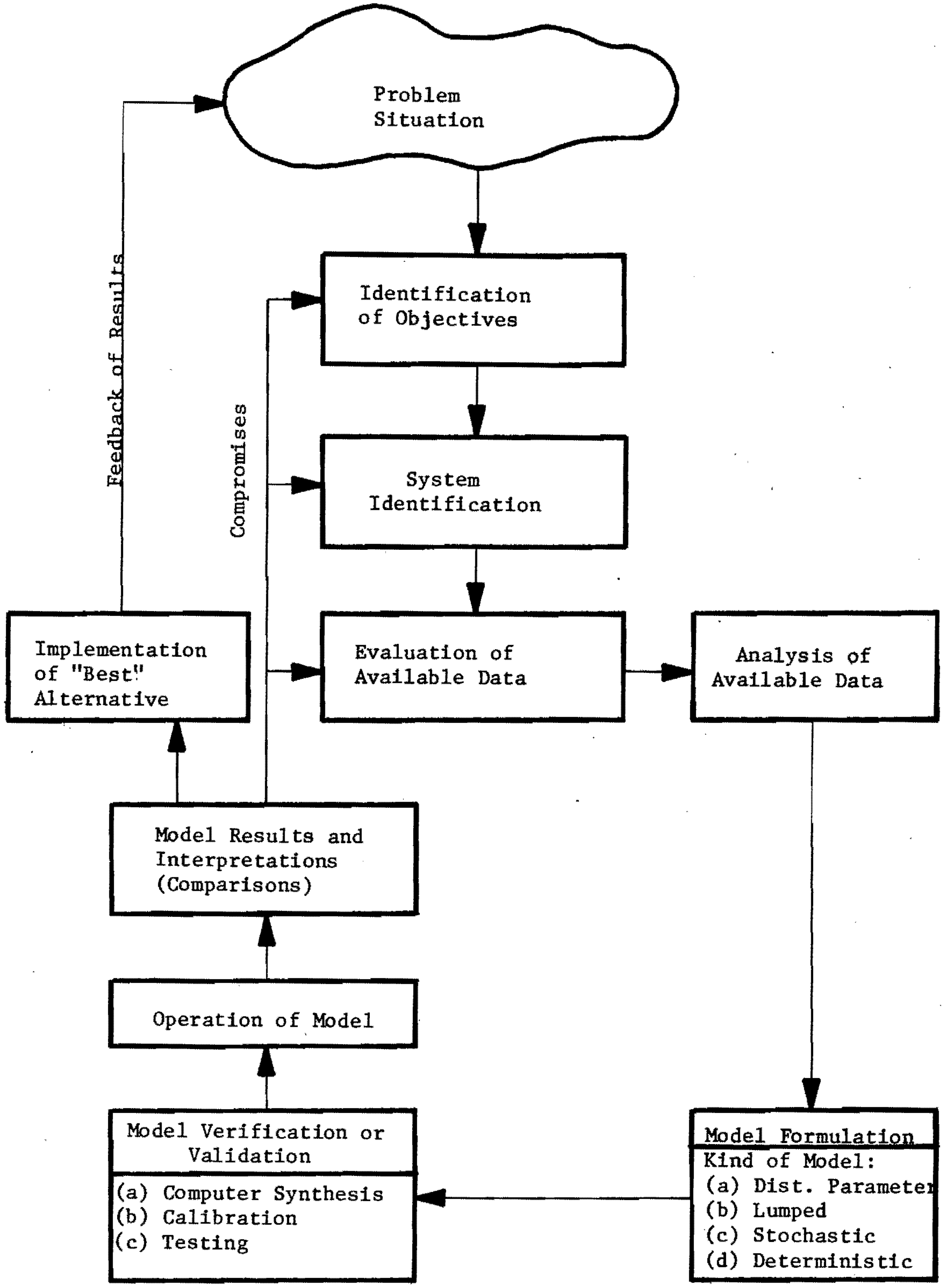
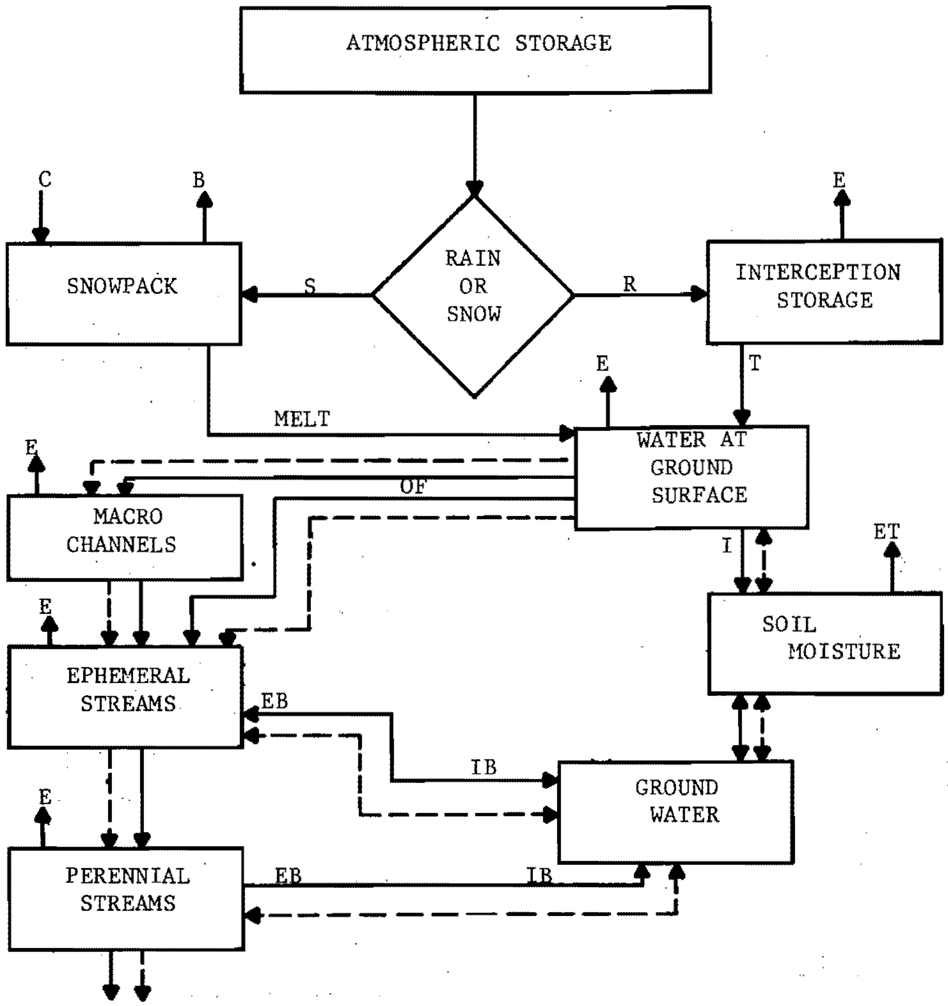


Figure 5.1. Steps in the development and application of a simulation model (taken from Riley et al. 1974).

GENERALIZED NATURAL HYDRO/SALINITY SYSTEM



Water

Salt

FLOW PATHS

E - Evaporation
ET - Evapotranspiration
B - Sublimation
C - Condensation
DP - Deep Percolation
S - Snow
R - Rain
OF - Overland Flow
I - Infiltration
EB - Groundwater Discharge
IB - Groundwater Recharge

Figure 5.2. Idealized natural hydrosalinity system.

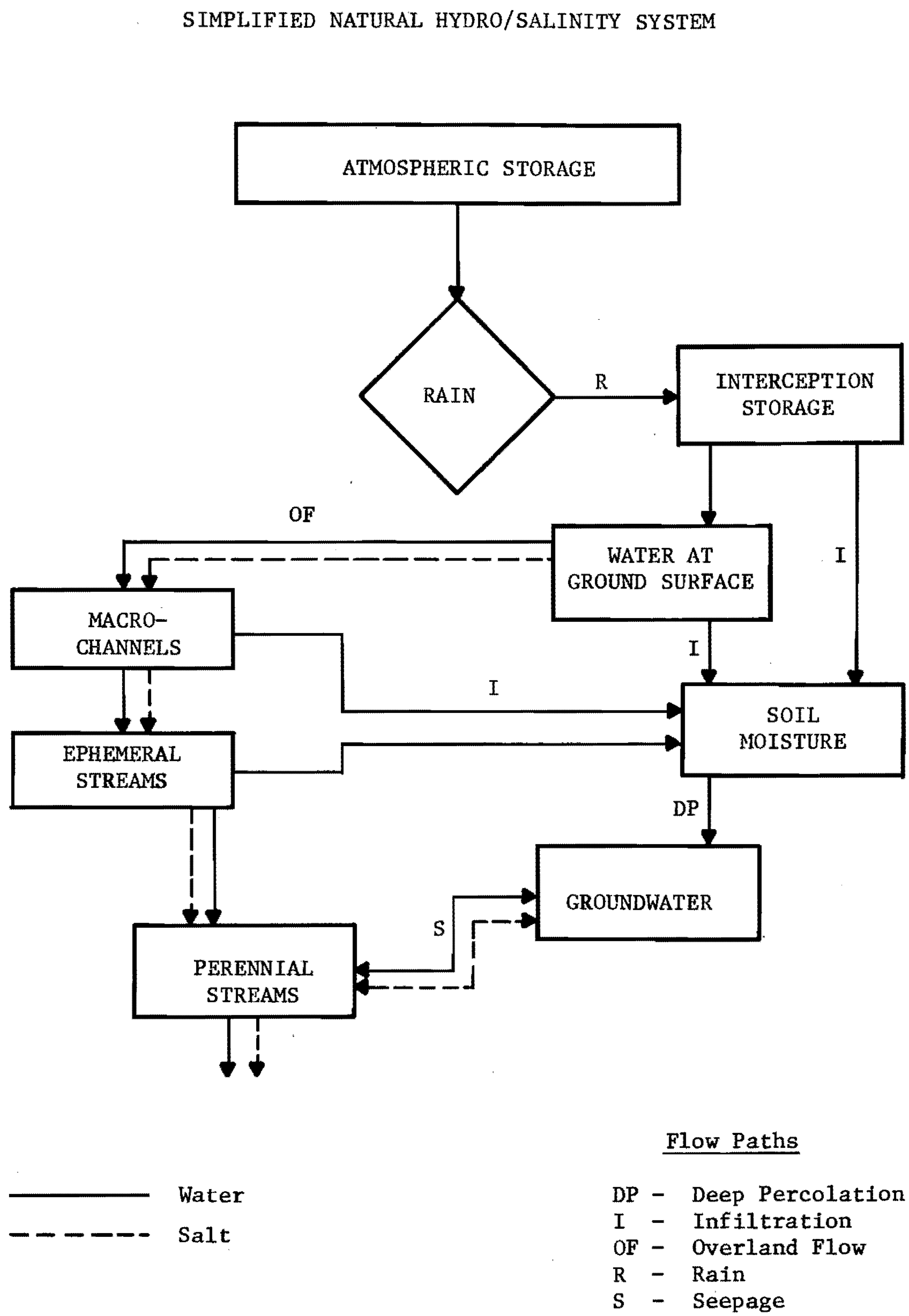


Figure 5.3. Simplified conceptual natural hydrosalinity system.

terns characteristic of the hydrologic region from the few events recorded annually at any one gaged site in this arid climate. Therefore the use of storms generated from regional data as being characteristic of and equally likely to occur anywhere in the Price River valley was judged superior to use of a measured data sequence at a specific site. Regional storm generation requires the development of probability distributions for principal storm pattern characteristics. These probability distributions also provide a potential for generating storm events of a preselected frequency.

The five factors used in developing these probability distributions were time of year, probability of a storm occurring, amount of precipitation, storm duration, and precipitation distribution during the storm. Time-of-year variability was handled by developing separate distributions for the other four variables for each month (April through October) and combining consecutive months with like distributions where possible. These four variables were specifically handled as follows:

1. For each month, the number of days having measurable precipitation was determined and plotted as shown for June in Figure 5.4. A line fit by the Gumbel distribution is shown plotted through these points. Regressions were run for the number of days of precipitation in a given month on the number of days in the preceding month, but low correlations led to dropping the number of rainy days in the preceding month as a significant variable.

2. Also for each month, the depths of precipitation on days with storms were plotted as shown for May in Figure 5.5. A line fit with a log-normal distribution is shown.

3. Since storm duration varies with storm depth, the storms were divided into five depth ranges and durations were separately plotted by range as shown in Figure 5.6.

4. A characteristic storm hyetograph shape was developed from recording precipitation gages in the Price and nearby Green River Basins with the results shown in Figure 5.7. Use of this shape neglects the possibility of more than one storm occurring in the same day.

The plotted information for these four distributions for the corresponding month provided the data used in Subroutine RAIN to

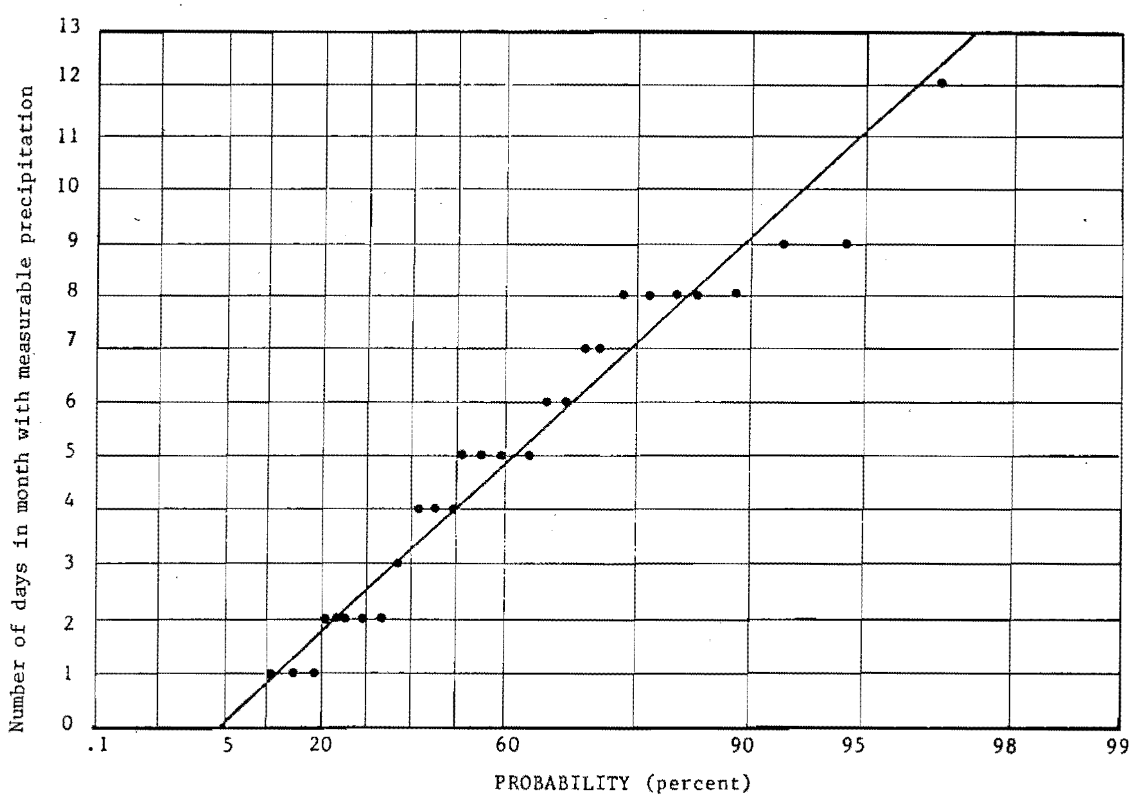


Figure 5.4. Gumbel distribution of days with precipitation in June. Weather data were taken from U.S. Weather Bureau station records in the Price and San Rafael River Basins.

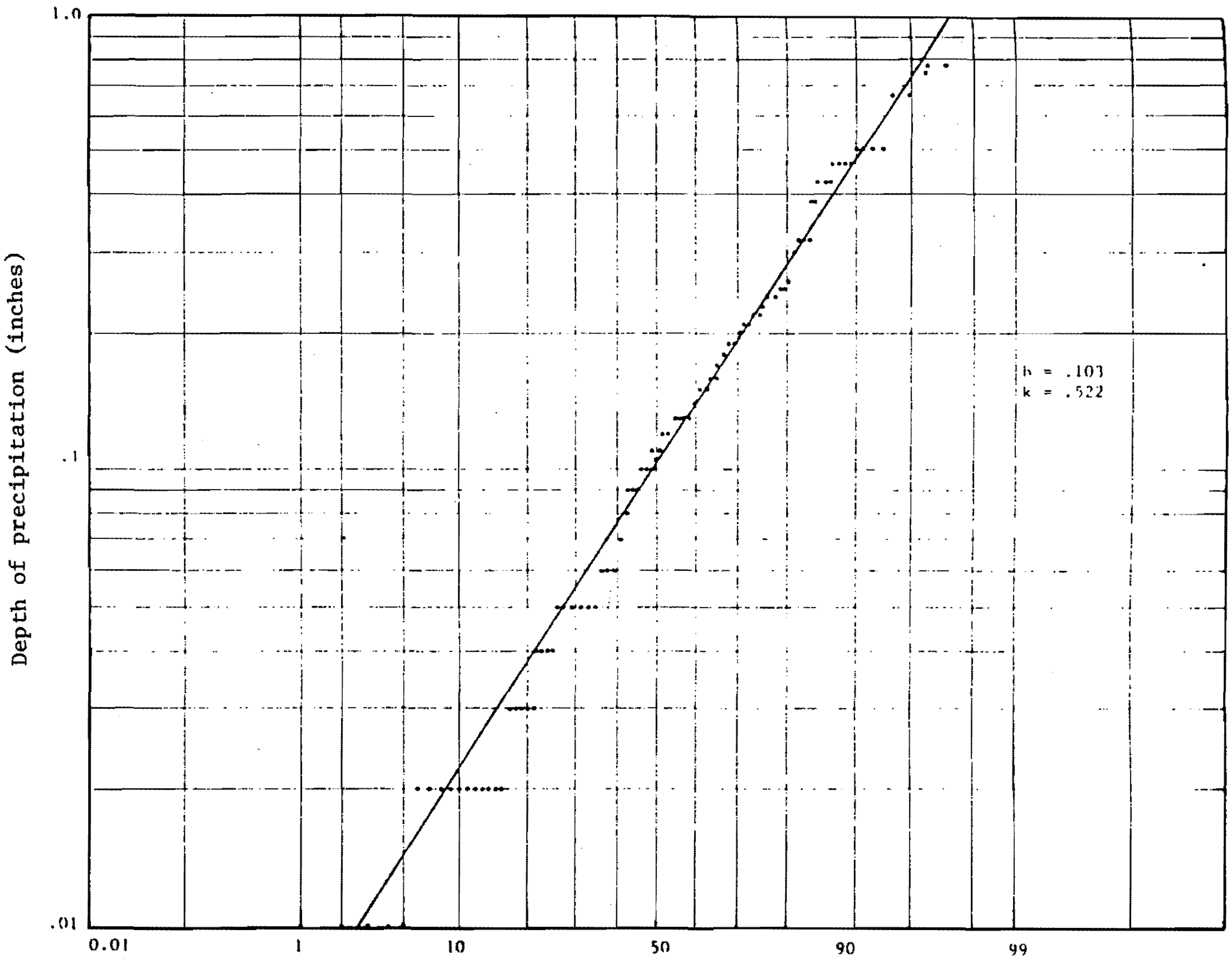


Figure 5.5. Log-normal distribution of daily precipitation for May. Weather data were taken from U.S. Weather Bureau station records in the Price and San Rafael River Basins.

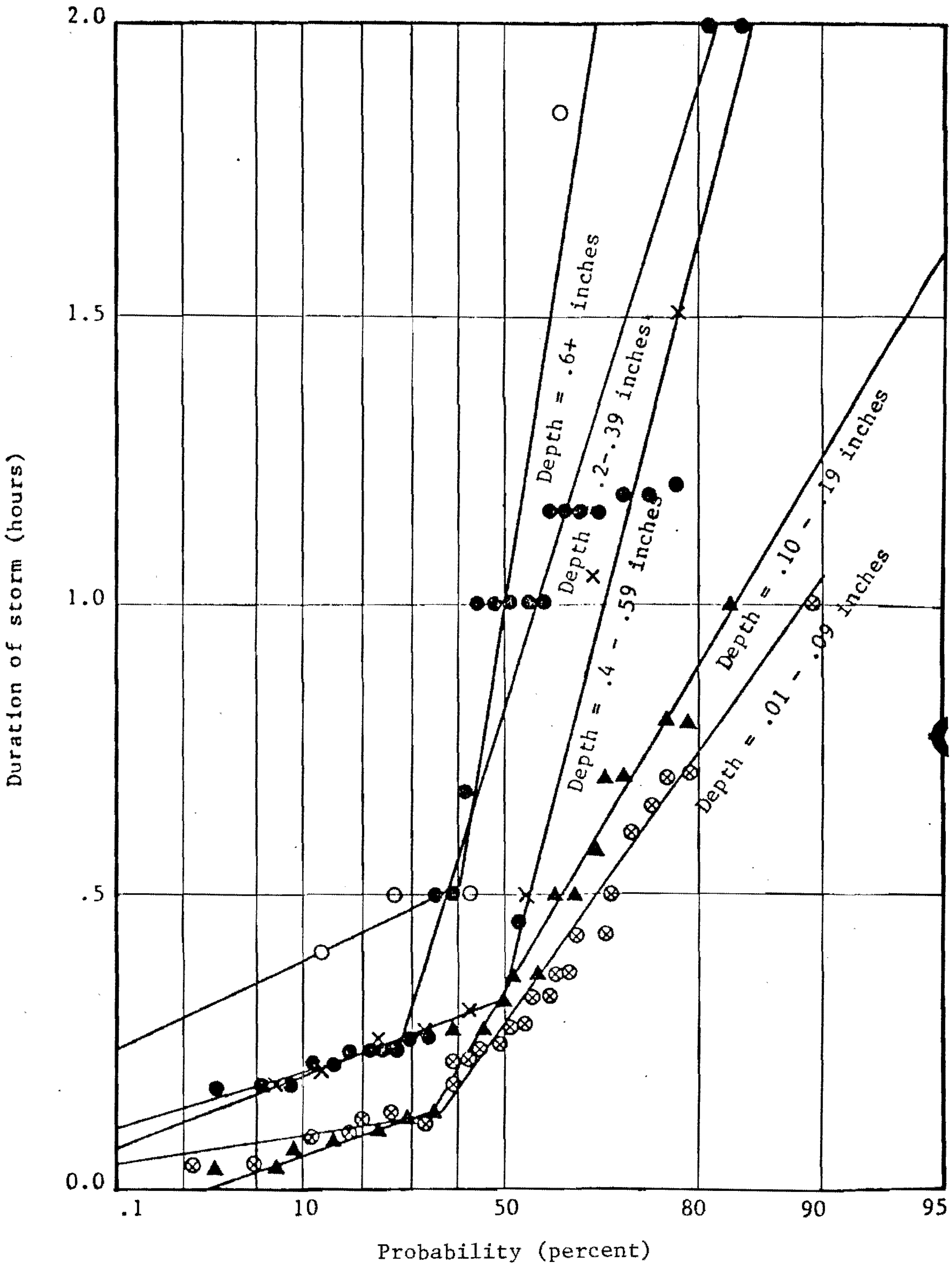


Figure 5.6. Normal distribution of storm runoff for June, July, and August. Weather data taken from U.S. Weather Bureau stations in the Price and nearby Green River Basins as well as a recording gage in the Coal Creek Basin operated by Utah State University.

generate storm hydrographs in the following procedure:

1. Select a number of rainy days at random (or as associated with the desired probability) from Figure 5.4.

2. Select the dates of these rainy days at random from the number of dates in that month of the year.

3. For each selected date for a rainy day, select a depth at random from Figure 5.5 and an associated duration from Figure 5.6.

4. Divide the storm duration into five equal increments and distribute the depth among those increments to form a hyetograph of the shape of Figure 5.7.

For an overview of how well subroutine RAIN matches actual precipitation patterns, simulated and recorded monthly rainfall averages and standard deviations for a 24-year period are tabulated in Table 5.1. Storm intensity comparisons would be better for assessing how well the model will match runoff peaks and associated sediment and salt loads, but there were no data for

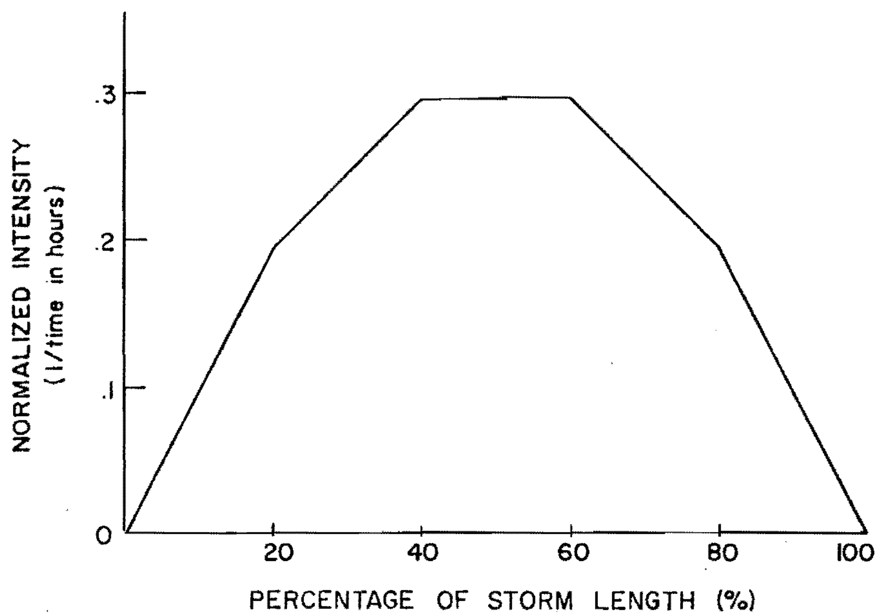


Figure 5.7. Characteristic storm hyetograph.

Table 5.1. Comparison of output from subroutine RAIN with monthly recorded rainfalls.

Month	Actual Precipitation[a] Average Precipitation (inches)	Actual Precipitation[a] Standard Deviation (inches)	RAIN Results Average Precipitation (inches)	RAIN Results Standard Deviation (inches)
April	0.59	0.52	0.51	0.44
May	0.72	0.74	0.65	0.79
June	0.94	0.93	1.13	0.96
July	0.98	0.74	1.21	1.05
August	1.11	0.97	1.06	0.91
September	1.15	1.18	1.30	1.37
October	1.26	1.29	1.55	1.48

[a]Obtained from precipitation gages in the Price River Basin.

this purpose besides those used to develop the model. As Table 5.1 shows, RAIN produced standard deviations which are very close to actual values and average monthly totals a little but not significantly higher than recorded values. A listing of the model is contained in Appendix E (Table E.2).

Precipitation excess (HYDRGY)

Surface runoff (overland flow) picks up salt and transports it to the channel. The second subroutine was developed to calculate surface runoff from the storm hyetographs produced by RAIN. This subroutine (HYDRGY) was modified from previous work (Riley et al. 1974) to fit the needs of this study.

The subroutine subtracts interception and depression storages from the first part of the rainfall hyetograph. Then infiltration begins. The infiltration rate is assumed to decline exponentially from a field measured maximum rate when the soil is at the wilting point to a field measured minimum rate when the soil is at field capacity. Soil moisture conditions at the beginning of a storm dictate the initial point on the infiltration curve. The precipitation excess is estimated as the volume of the rainfall hyetograph minus interception and depression storage and minus an infiltration volume estimated from the infiltration curve. Negative values are taken to indicate no runoff.

The HYDRGY subroutine is initialized with a beginning soil moisture. HYDRGY determines the soil moisture recharge during storms. A subroutine (CONSUM) employs the Jensen-Haise consumptive use equation (Jensen 1973) to determine soil moisture depletion between storms. These two subroutines therefore maintain a running estimate of the antecedent moisture level for use by HYDRGY in computing the precipitation excess during each storm. A listing of the two subroutines HYDRGY and CONSUM is in Appendix E.

Surface runoff (SRO)

This component of the model routes the precipitation excess generated by HYDRGY through the successive surface runoff stages of overland flow, microchannel flow, and primary channel flow. Three flow routing techniques were considered. Two were the Saint-Venant equations described by Jeppson (1974) and the kinematic wave equations described by Henderson (1971). However, neither of these techniques was adopted because of extensive data requirements on flow and channel characteristics. The relatively simple Muskinghum routing equation (Linsley and Franzini 1972) was considered satisfactory for the small watersheds of this study. Henderson (1971) noted that the Muskinghum technique provides a fair approximation for natural floods in rivers whose slopes exceed 0.002.

Given an estimated inflow volume to the study area from upstream, a hydrograph was formed by:

$$L_t = I_{base} + A_0 \cdot [1 - \cos(a \cdot t)] \qquad (5.1)$$

in which

L_t = Channel inflow at time t
I_{base} = Base channel inflow
A_0 = One-half hydrograph peak inflow
a = Constant, $2\pi/T$
T = Tributary basin time to peak

The inflow is then routed down successive storage reaches by the Muskinghum method. Lateral inflow, groundwater inflow, seepage, and diversions are added at the top of a reach.

The Muskinghum coefficients K and X were adjusted to provide the best reproduction of observed hydrographs following a method described in Chow (1964). Once calibrated, the coefficient X was assumed constant and the coefficient K was varied with the flowrate. Stability of the Muskinghum method is generally insured when:

$$2\,K\,X < \Delta t < K \qquad (5.2)$$

in which

K = Time routing constant
X = Inflow effect routing constant
Δt = The time step

Failure to select a time step for routing that meets these conditions may result in oscillating flow values or other errors (Linsley and Franzini 1972).

Overland flow and lateral channel storm event flows are routed to the main channel by assuming that the flows can be represented as two linear reservoirs in series (Chow 1964). Storage is assumed to be directly proportional to outflow.

$$S = K_2\,\theta \qquad (5.3)$$

in which

S = Storage
θ = Outflow
K_2 = Storage coefficient

The first order finite differencing of Equation 5.3 with respect to time followed by algebraic manipulation gives:

$$\theta_2 = \theta_1 + C\,(I_1 - \theta_1) + 1/2\,C\,(I_2 - I_1) \qquad (5.4)$$

$$C = \frac{\Delta t}{K_2 + 1/2\,\Delta t} \qquad (5.5)$$

in which

θ = Outflow at subscripted time
C = Routing coefficient
I = Inflow at subscripted time

The surface runoff is routed to the upper reaches of a microchannel. The microchannel flow is routed to the top of a reach in the next order channel. In the Price River Basin, lateral channels on the valley floor are normally ephemeral. In the model, these channels are assumed to have infiltration characteristics similar to those of the overland soil surface. For perennial streams, such as Coal Creek, channel seepage and groundwater inflow rates are estimated from field observations. The channel routing subroutine described above is listed in Appendix E, Table E.2.

Salinity Component (SALIN)

The hydrographs of precipitation excess produced by HYDRGY, as routed and combined downstream, are used as inputs to the salt loading functions in SALIN.

Overland flow salt loading

The overland flow salt loading function was taken from Ponce (1975) to be of the form:

$$TDS = B_0 + B_1 x_1 + B_2 x_2 \quad . . . . . . \quad (5.6)$$

in which

TDS = Concentration of total dissolved solids in mg/l
x_1 = Precipitation intensity in depth per unit time
x_2 = Rate of precipitation excess in depth per unit time

Ponce's calibrations for various Mancos Shale members are shown in Table 5.2. His low mean r^2 value of 0.46 suggests that additional independent variables should also be explored. His large values for B_0 compared to B_1 and B_2 suggest the same need. In attempting to add one more variable, Ponce was not able to detect any effects on salinity concentration of distance traveled by overland flow.

Channel salt loading

The accumulated salt load from surface channels was estimated by Equation 4.5, using the average salt loading rate of 2.51 gms/min$^{0.5}$ for all locations and stream orders. The salinity uptake with respect to time was estimated by forward finite differencing.

In order to estimate the channel length parameter required by Equation 4.5, Horton's Law of Streams (Chow 1964) was applied to the area being modeled. Coal Creek was identified as a fourth order stream (Strahler 1957), and its tributary channels were ordered as on Figure 5.8. Data on drainage areas and channel lengths were obtained from topographic maps and aerial photographs and plotted for the Coal Creek drainage. These lines were extrapolated to stream order 1. From Figure 5.8, estimates were made of the length of channels of a given order.

Mean channel cross-sections with respect to order were estimated from field observations, and the mean wetted perimeters were estimated by Dixon (1977):

$$\overline{WP} = a\,\overline{Q}^b \quad . . . . \quad (5.7)$$

in which

$\overline{WP}$ = Mean wetted perimeter
$\overline{Q}$ = Mean flow
a,b = Constants

Flows in the tributaries (orders 3, 2, and 1) are routed to Coal Creek by assuming that the source areas are uniformly distributed throughout the tributary area during the previous time step. The time-dependent salt release is initiated at the beginning of overland flow and continued until re-

Table 5.2. Coefficients of overland flow load function for the various members of the Mancos Shale (Ponce 1975).

Mancos Member	B_0 (mg/l)[a]	B_1 ppm (hr/in)	B_1 mg/l (hr/mm)	B_2 ppm (hr/in)	B_2 mg/l (hr/mm)
Masuk	30.70	0	0	- 0.01	-0.0003
Upper Blue Gate	274.64	11.77	0.4633	- 3.66	-0.1441
Middle Blue Gate	52.44	0.92	0.0364	- 1.09	-0.0429
Lower Blue Gate	324.18	-0.36	-0.0143	0.22	0.0087
Tununk	119.14	-0.09	-0.0035	- 0.08	-0.0031
Mancos Undivided	366.68	60.97	2.4004	-72.76	-2.8644

[a]mg/l is equal to ppm at TDS values below 7000 ppm.

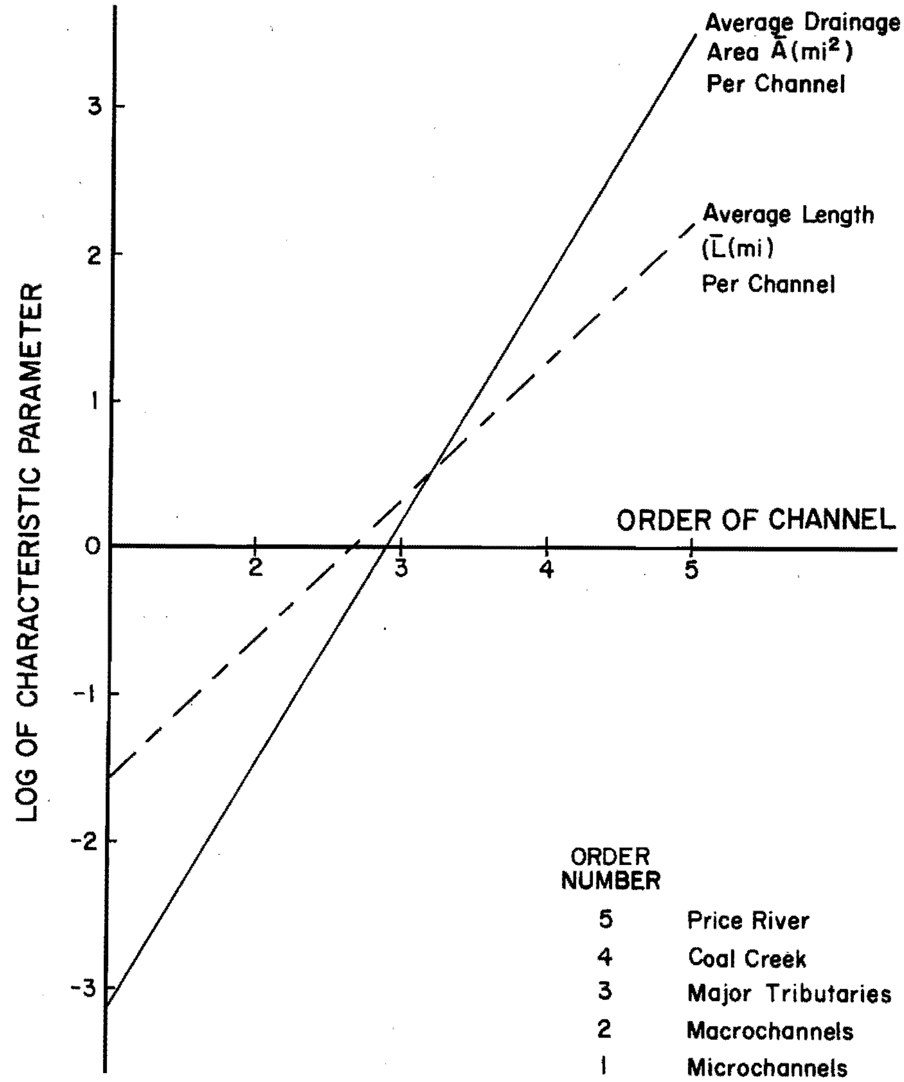


Figure 5.8. Drainage characteristics of the Coal Creek subbasin.

initialization of the model at the beginning of the next storm.

To estimate salt uptake in the Coal Creek channel (order 4), the cross-section was divided into equal depth increments (Figure 5.9). An increment of wetted perimeter was associated with each depth.

Salt is routed down the primary channel by assuming that each reach is completely mixed. The assumption tends to lower the magnitude of the halograph but permits a relatively stable, explicit, and simple solution algorithm. A time-averaged mass balance equation is

$$C(I,J) = \Bigg\{ C(I,J\text{-}1) \cdot \text{Ɏ}\,(I,J\text{-}1) + \left(\frac{Q_\Theta(I\text{-}1,J\text{-}1)\cdot C(I\text{-}1,J\text{-}1) + Q_\Theta(I\text{-}1,J)\cdot C(I\text{-}1,J)}{2}\right) \cdot \Delta t + Q_s(I) \cdot \left(\frac{C(I\text{-}1,J\text{-}1) + C(I\text{-}1,J)}{2}\right) \cdot \Delta t + M\,(I) - C_\Theta(I,J\text{-}1)\cdot Q_\Theta(I,J\text{-}1)\cdot\left(\frac{\Delta t}{2}\right)\Bigg\} \Big/ \text{Ɏ}\,(I,J) + Q_\Theta\,(I,J)\cdot\left(\frac{\Delta t}{2}\right) \quad \ldots . \; (5.8)$$

in which

$C(I,J)$ = Average salinity in reach I at time J
I-1 = Upstream reach
J-1 = Previous time step
Q_s = Seepage
Q_θ = Reach outflow
C = Concentration
$\forall$ = Storm volume in the reach I
Δt = Time step
M = Salt mass pickup

The stability of Equation 5.8 requires:

1. Continuity of flow with respect to the primary channel.
2. $Q_s(I) < Q_\theta\ [(I-1,\ J) + Q_\theta\ (I-1,\ J-1)]/2$
3. $\Delta t < 2 \cdot \forall\ [(I,\ J-1)/Q_\theta\ (I,\ J-1)]$

A listing of the program is in Appendix E (Table E.2). Also included is a listing and description of the model parameters, input data, and format required by the model. The one-dimensional model simulates storm hydrographs and halographs, assuming the intrinsic salinity sources to be homogeneous and uniformly distributed across the watershed and salinity uptake to be additive and conservative. For modeling areas without irrigated agriculture, groundwater flow was not considered significant and was not included in the model.

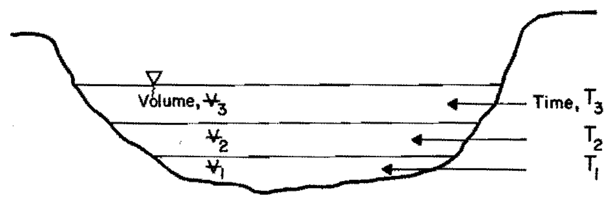


Figure 5.9. Primary channel wetted perimeter subdivision.

CHAPTER VI

MODEL APPLICATION TO THE COAL CREEK DRAINAGE

Application Procedure

The hydrosalinity model of Chapter V was applied to the Coal Creek subbasin. The following methods were used in process representation:

1. The rainfall and precipitation excess values were generated by the methods described above to represent Price River valley meteorological conditions and the response of the natural system.

2. Overland flow and the flow in channels of stream order 3 or less were routed by assuming storage to be a linear function of outflow, and larger channel flows were routed by the Muskinghum equation.

3. Salt pickup from overland flow was estimated by Equation 5.6.

4. Salt loading within a particular order of channel was assumed to be uniform and represented by Equation 4.5.

The Coal Creek drainage was subdivided into nine subbasins (five entering from the right and four from the left) as shown on Figure 6.1. The main tributaries and their

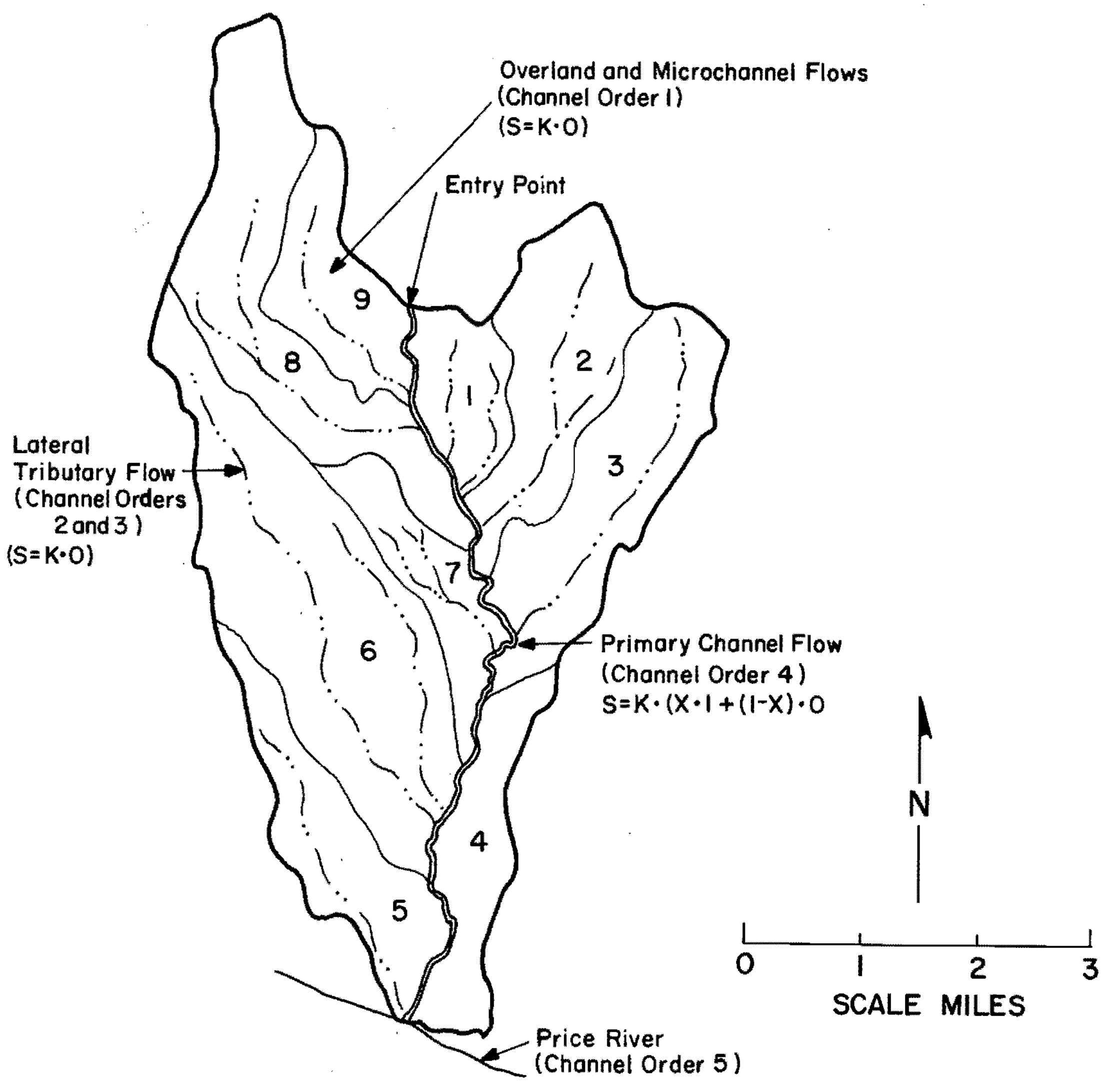


Figure 6.1. The subbasins and macrochannels of the Coal Creek drainage.

feeder channels (channel orders 3 and 2, respectively) are shown. The main stem of Coal Creek was subdivided into ten reaches of equal length, each approximately 0.82 mi long (Figure 6.2). Each reach was assumed to have a uniform channel cross-section and salt producing potential. A constant Muskinghum routing coefficient was used for each reach (Table 6.1).

Headwater baseflow, channel seepage, and groundwater inflow values are also listed in Table 6.1. Precipitation and precipitation excess values obtained from the RAIN and HYDRGY subroutines are given in Appendix E. Table 6.2 gives routing coefficients for surface runoff and for tributary channels (orders 1, 2, and 3).

For overland flows, coefficients for predicting salt pickup as a function of geologic member are given by Table 5.2. Channel (orders 1, 2, 3, and 4) salt pickup characteristics are listed in Table 6.3.

The model was run in timesteps of 20 minutes, and steady state conditions were achieved after 90 timesteps. An illustrative model response for 2 mm of surface runoff is illustrated in Figure 6.3. The salt concentration peaked at the beginning of the flood hydrograph and then rapidly dropped to a low value during the bulk of the flow. At the tail of the flood hydrograph, the concentration slowly rose again because of reduced dilution. Finally, the concentration dropped as inflows from lateral channels ceased, and the remaining flow drained from storage in the main channel.

In the model, the salt concentration may be linearly adjusted by varying the salt loading coefficients. The second salt concentration rise may be varied independently of the first by adjusting 1) the time of

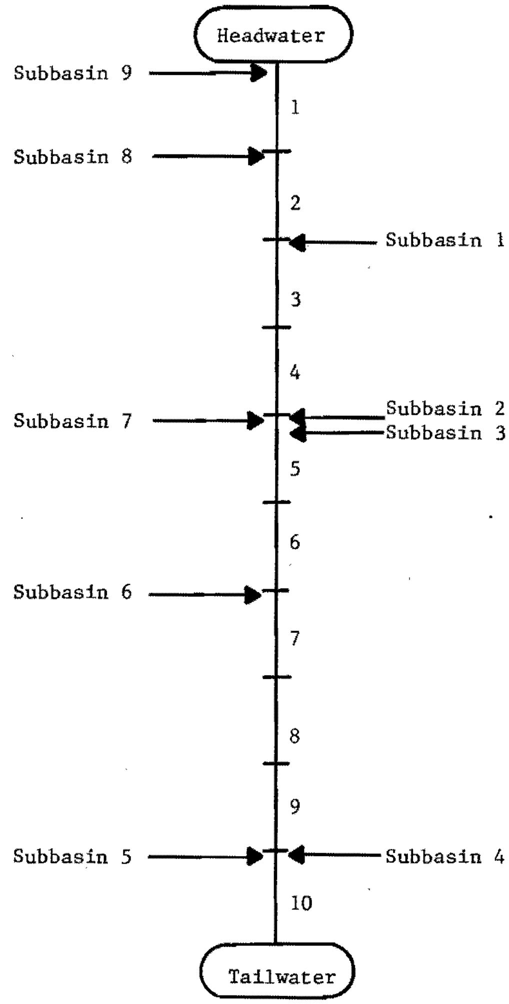


Figure 6.2. Model representation of Coal Creek.

Table 6.1. Primary channel characteristics.

Reach Number	Wetted Perimeter Coefficients		Groundwater Inflow	Concentration Groundwater	Channel Seepage	Muskinghum Routing Coefficients	
	A	B	m^3/min	mg/l	m^3/min	K(min)	X(min)
1	2.1	0.4	0.0	2200	-0.00056	30.	0.3
2	2.1	0.4	0.0	2200	-0.00056	30.	0.3
3	2.1	0.4	0.0	2200	-0.00056	30.	0.3
4	2.1	0.4	0.0	2200	-0.00056	30.	0.3
5	2.1	0.4	0.0022	2200	-0.00056	30.	0.3
6	2.1	0.4	0.0	2200	-0.00056	30.	0.3
7	2.1	0.4	0.0	2200	-0.00056	30.	0.3
8	2.1	0.4	0.0	2200	-0.00056	30.	0.3
9	2.1	0.4	0.0	2200	-0.00056	30.	0.3
10	2.1	0.4	0.0	2200	-0.00056	30.	0.3

Headwater base flow = 1.704 m^3/min.

Table 6.2. Subbasin characteristics.

Subbasin Number	Area	Overland Flow Routing Coefficient	Tributary Flow Routing Coefficient
	(km^2)	(min.)	(min.)
1	2.823	11.	47.
2	6.035	11.	57.
3	7.122	11.	57.
4	3.937	11.	15.
5	4.869	11.	62.
6	14.711	11.	72.
7	3.263	11.	21.
8	8.366	11.	62.
9	4.455	11.	31.

application of the second salt loading coefficient, and 2) the value of the second coefficient. However, data were not available for model validation.

Simulation Results

Estimated salt output from Coal Creek

The model was run utilizing generated precipitation data for a 3-year period. The simulated annual and average salt loads by source are given in Table 6.4. The average estimated salt load from the natural channels and overland flow is 121 x 10^7 gms per year.

Table 6.3. Channel and salt loading characteristics.

Stream Order	Mean Length (m)	Mean Density km/km^2	Wetted Perimeter Coefficients A	Wetted Perimeter Coefficients B	Salt Pickup Rates: Initial K (gm/m^2-$min^{0.5}$)	Salt Pickup Rates: K after 10,000 min. (gm/m^2-$min^{0.5}$)
1	45.	57.10	2.33	0.245	0.233	0.120
2	404.	12.80	2.24	0.29	0.233	0.120
3	3211.	2.86	2.14	0.34	0.233	0.120
4	32110.	0.57	2.10	0.40	0.233	0.120

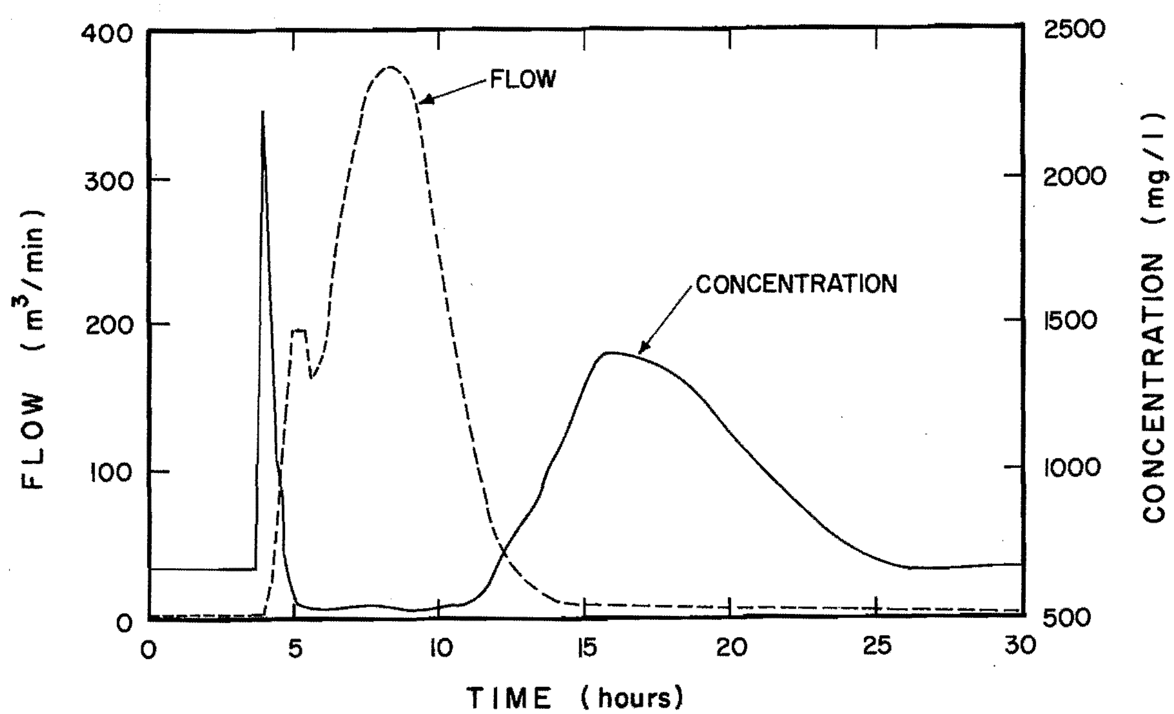


Figure 6.3. Model response to 0.2 mm of surface runoff (lower Coal Creek site).

Table 6.4. Simulated annual salt load from natural channels in the Coal Creek study area.

Salt Source		Year 1	Year 2	Year 3	Average
Overland	Yield (gms)	51.17 x 10^7	159.62 x 10^7	80.24 x 10^7	
	Percent	77	83	76	79
1st Order Channels	Yield (gms)	7.98 x 10^7	16.61 x 10^7	13.13 x 10^7	
	Percent	12	9	12	11
2nd Order Channels	Yield (gms)	3.80 x 10^7	8.00 x 10^7	6.35 x 10^7	
	Percent	6	4	6	5
3rd Order Channels	Yield (gms)	2.46 x 10^7	5.23 x 10^7	4.16 x 10^7	
	Percent	4	3	4	4
4th Order Channels	Yield (gms)	0.78 x 10^7	1.88 x 10^7	2.05 x 10^7	
	Percent	1	1	2	1
Total	Yield (gms)	66.19 x 10^7	191.34 x 10^7	105.93 x 10^7	

Model sensitivity

A sensitivity analysis of the model was conducted. Table 6.5 lists the important model parameters in order of decreasing effect on results. The value used for each parameter in the simulation runs is also given. As can be seen, the model is most sensitive to parameters which significantly affect the predicted runoff.

Estimated salt output as Woodside

If Coal Creek is representative of the natural channels in the Price River Basin, these results may be extrapolated to estimate salt loading values at Woodside. For this extrapolation, the area of exposed undivided Mancos Shale within the Coal Creek study section was estimated from soils maps to be 21.46 square miles. Ponce (1975) estimated

Table 6.5. Coefficient values for application of the hydrosalinity model of the Coal Creek drainage.

Parameter(s)[1]	Description	Value Used
FC	Minimum infiltration capacity rate (inches/hr)	Depends on shale
A,B,C	Shape factors of characteristic hyetograph	-3.2, 4.8, -0.6
SI	Upper limit of interception depression storage (inches)	0.05
SS	Saturated soil level (inches)	3.0
DKT	Decay constant in infiltration equation (hr^{-hr})	20.0
AREA	Microchannel drainage area (acres)	0.51
CHANL	Microchannel length (feet)	120.0
XCHCO	Factor to adjust salt pickup for length of channel	0.4
WP	Wilting point of soil (inches)	0.5
TELIM	Upper limit on precipitation intensity allowed (inches/hr)	1.5
XKC2	Consumptive use coefficient of native vegetation	0.89
FICAP	Field capacity of soil (inches)	2.0
FO	Initial infiltration capacity rate (inches/hr)	Depends on shale
XKC1	Consumptive use coefficient of native vegetation	0.58
SMOIS	Initial soil moisture level (inches)	1.0
TAVSW	Decay constant in surface water routing (hr^{-hr})	5.0
IFRS	Beginning of frost free season (Julian day)	135
IFRF	End of frost free season (Julian day)	275

[1]Listed in order of decreasing model sensitivity.

that 468 square miles of Mancos Shale are exposed in the Price River Basin. Extrapolating by the ratio of these areas (a factor of 21.8) gives the loadings on Table 6.6. Ponce (1975) estimated the average annual salt load at Woodside as 3.68 x 10^8 kg.

As found by Ponce (1975) and White (1977a), the extrapolated model results, when compared with the total salt load, suggest that the salt loads from overland flow and natural channels are a small portion of the total. These results are believed to be reasonably representative of long periods of time. The overland flow salt load is dependent upon the variables (precipitation intensity and peak runoff rate) of Equation 5.6. The channel salt load is directly proportional to the salt loading coefficient of Equation 4.5 and is sensitive to the routing coefficients and channel characteristics applied in the model. None of these inputs change drastically from year to year.

Because the amount of salt pickup varies considerably with the type of Mancos Shale over which the runoff passes, an attempt was made to refine the estimates of Table 6.6 by taking into account the different types of exposed shale within the valley floor area. For simplicity and because they supply most of the salt loading to surface runoff (Table 6.6), only overland and microchannel flows were included in this analysis. Furthermore, the following simple relationship was adopted as the microchannel salt loading function.

$$y = a\,x^b \quad \ldots \ldots \ldots \ldots \quad (6.1)$$

in which

y = The mass of salt pickup
x = The accumulated runoff volume for a particular event
a and b = Constants for a particular shale type

Values of a and b in Equation 6.1 were developed for the six Mancos Shale soils. Data obtained 100 feet downstream in microchannel studies conducted by White (1977) in various shale types (Figure 6.4) were used to estimate accumulated salt mass for various accumulated flows (Table 6.7). These reults were used to estimate the values for a and b given in Table 6.8.

In order to apply Equation 6.1 to the various areas of shale within the basin, Figure 5.8 was used to estimate an average microchannel length and order for each shale type for each area included in the analysis. To adjust the salt loading estimates of Equation 6.1 for channel lengths other than 100 feet, data from Table 6.7 were used. For each shale type, salt loading was found to vary with channel length to the 0.4 power (Figure 6.5).

Subroutines RAIN and HYDRGY (Chapter V) were coupled to the appropriate relationship by shale type for overland flow (adjusted by data from Table 5.2) and microchannel flow (adjusted by data from Table 6.9 and by Figure 6.5). The resulting model (listed in Appendix E, Table E.3) was operated over a 3-year period. The results, summarized by Table 6.9, suggest that the division of the salt contribution between microchannel and overland flow processes is extremely variable

Table 6.6. Extrapolated annual salt load at Woodside.

Source	Annual Salt Load	
	kg	Tons
Overland Flow	2.11 x 10^7	23,250
1st Order Channels	2.74 x 10^6	3,000
2nd Order Channels	1.32 x 10^6	1,450
3rd Order Channels	8.61 x 10^5	950
4th Order Channels	3.42 x 10^5	375
Totals	2.64 x 10^7	29,025

Table 6.7. Accumulated salt mass vs. accumulated flow for various shale types (from White 1977).

Accumulated Flow of Water at 100-Foot Station (ft^3)	Accumulated Salt Mass at 100-Foot Station (gms)					
	Undivided Shale	Upper Blue Gate Shale	Middle Blue Gate Shale	Lower Blue Gate Shale	Tununk Shale	Masuk Shale
0	0	0	0	0	0	0
10	105	320	400	10	7	12
20	195	575	700	17	12	20
30	265	870	950	32	20	27
50	385	1355	1350	44	27	40
100	685	2200	2400	58	50	80
200	1335	3045	3500	96	88	132
300	1540	3950	3900		110	
400	1670		4900		120	
600	1955					
800	2120					

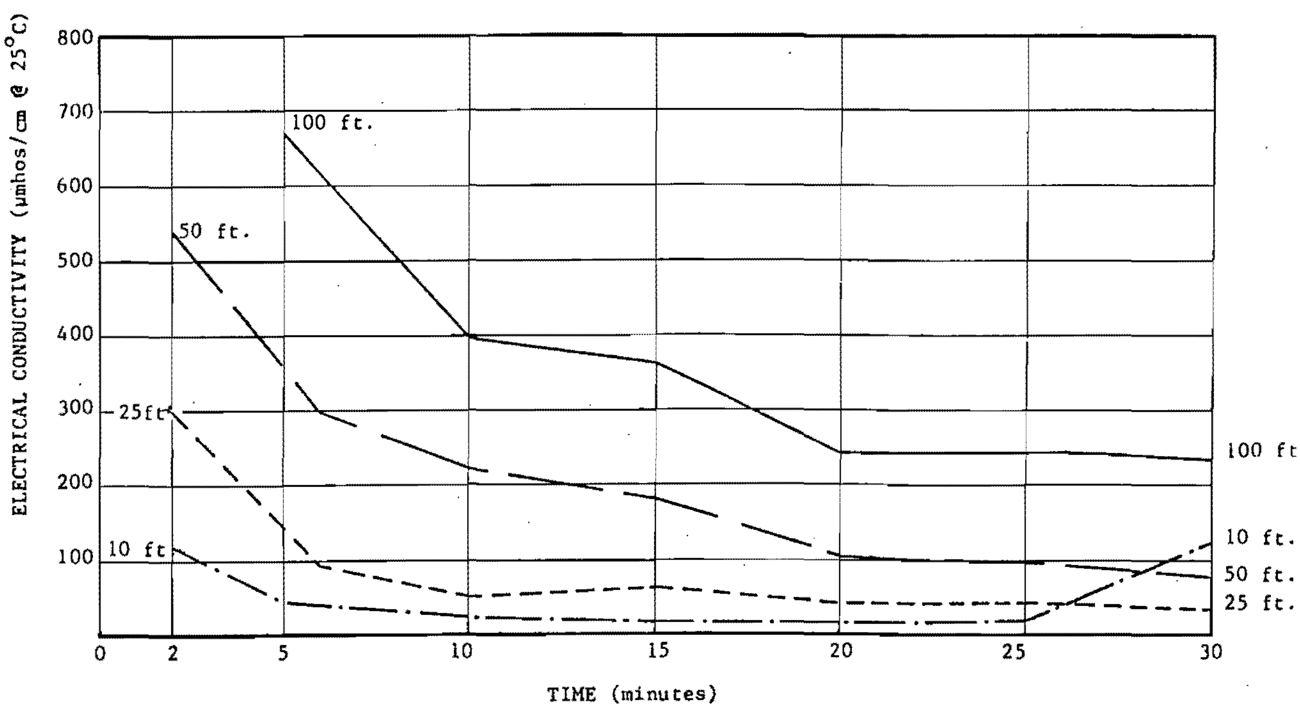


Figure 6.4. Conductivities as a function of time for different channel distances traveled (from field work done by White 1977a).

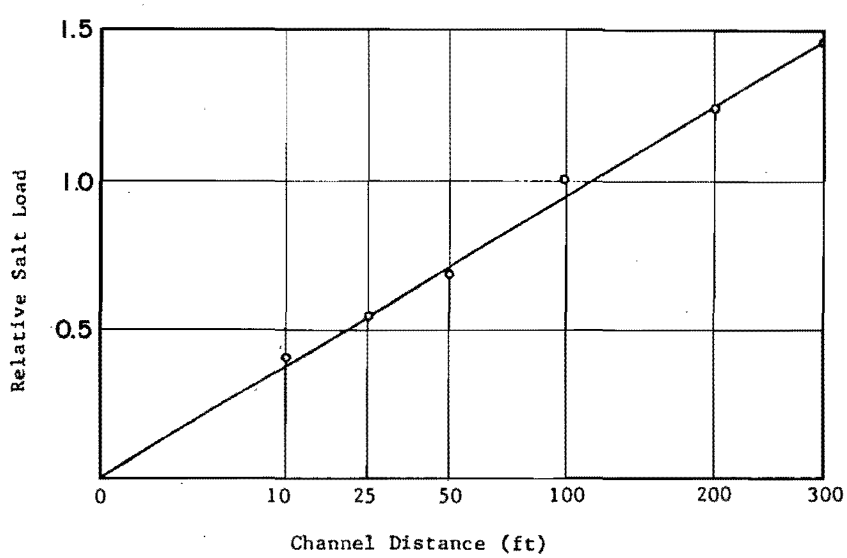


Figure 6.5. Salt load as a function of channel distance to the 0.4 power.

Table 6.8. Coefficients in the microchannel salt loading function $y = ax^b$.

Shale Type	a	b	r^2
Undivided	23.9	0.71	0.981
Upper Blue Gate	66.8	0.73	0.986
Middle Blue Gate	94.0	0.67	0.991
Lower Blue Gate	2.0	0.74	0.966
Tununk	1.2	0.79	0.993
Masuk	1.7	0.82	0.997

(predominantly from microchannel sources for Middle Blue Gate and predominantly overland flow for Lower Blue Gate). This variation is caused partially by the high degree of variability within the same geologic shale type.

Some types of shale were not sampled as intensely as others. Even so, comparison between Table 6.9 and the much larger loads of Table 6.6 is interesting. Table 6.6 is extrapolated on the assumption that all the shales in the basin are of the undivided type. Because of the relatively high salt producing potential of the undivided shale (see Table 6.9), this assumption would be expected to increase the predicted salt load from overland flows.

In contrast, there is a close agreement on the amount of salt at Woodside attributed to first order channels. This might have been expected because Ponce (1975) and White (1977) suggested that the pickup of salt is more influenced by shale type for overland flows than for channel flows.

The Utah Division of Water Resources (1975) estimated an average runoff coefficient of about 9 percent between Castle Gate and Woodside, with the valley portion of that section yielding less than 1 inch of water per year on the average. The model results for Coal Creek also estimated that an average of about 9 percent of the precipitation within this reach becomes surface runoff. If interflow and groundwater were added, the estimated basin yield would be somewhat greater, but these quantities are small on the valley floor area of the Price River Basin.

The reasonableness of these general comparisons and the lack of model sensitivity to the values given for input parameters confirm that the first generation model as programmed is on the right track. Field data for validity testing are needed for model refinement.

Table 6.9. Estimated salt production from surface flows for various shale types in the Price River Basin.

Shale	Salt Produced (lbs/acre/year)			Acres of Shale in Basin	Total Salt Produced in Basin (tons/year)		
	Micro-channel	Overland Flow	Total		Micro-channel	Overland Flow	Total
Undivided	24.1	71.5	95.6	119,000	1430	4250	5680
Middle Blue Gate	19.8	1.4	21.2	36,900[a]	365	25	390
Masuk	1.2	1.4	2.6	52,400	30	35	65
Tununk	1.0	7.9	8.9	14,400	7	57	64
Upper Blue Gate	48.7	30.0	79.2	36,900[a]	900	550	1450
Lower Blue Gate	1.2	21.5	22.7	36,900[a]	20	400	420
				TOTALS	2752	5317	8069
Percentage of salt produced by the basin[b]					0.68%	1.31%	2.0%

[a]Assuming equal areas of the three Blue Gate shale members.

[b]Using a total of 405,500 tons per year as estimated by Ponce (1975).

CHAPTER VII

BASIN-WIDE HYDROSALINITY STUDY

Introduction

Narasimhan et al. (1980) compared a number of hydrosalinity models and concluded that the models generally suffer the weaknesses of oversimplifications of 1) chemical processes, 2) surface-soil-groundwater interactions, and 3) salt pickup phenomena. Nevertheless, using one of the best of the available models, additional insight into water and salt flows within the Price River Basin was sought by applying BSAM1, developed by Huber et al. (1976). The model employs water and salt mass balance accounting on a monthly time interval through the representation of the hydrologic system shown in Figure 7.1. In the application, only the runoff and salt fluxes from the valley bottom lands were considered.

Data

The BSAM modeling was based on the USGS gaging station near Heiner, where Price River emerges from the mountains onto the valley floor for water years 1973 through 1975. Since that station was discontinued in 1969, regression analyses were performed correlating flows for each month of the year at Heiner during the 1960s with recorded flows at USGS gages at Willow Creek, Beaver Creek, White River, and Scofield Reservoir (all of which are upstream of Heiner--see Figure 1.1). During the winter months, only flows at Willow Creek and Scofield Reservoir were used because of inaccurate or incomplete records at the other two stations. Many combinations of recorded flow records were examined. The highest correlations are tabulated in Table 7.1.

Precipitation and temperature data from the weather stations at Hiawatha, Sunnyside, and Price Warehouse were also used as input data for BSAM. These stations are scattered within the basin and provide fairly representative temperature data. More precipitation gages would have been helpful. It is apparent from an examination of precipitation and streamflow records that localized thunderstorms causing significant runoff may miss all three precipitation gages. This causes error in the calibration of the model.

Gordon Creek and Desert Seep Wash, two major tributaries of the Price River, were modeled to estimate ungaged surface inflows of water and salt. These runs proved unsatisfactory in that there was more salt inflow than salt outflow, implying a net deposit of salt in the valley. Desert Seep Wash drains agricultural lands and, at the gaging station, is more indicative of agricultural loading than of natural inflows. Hence, Desert Seep Wash was not modeled further.

Records in the State Engineer's office were examined for canal diversion data. Canal water imported from the San Rafael Basin is not measured, and this quantity, therefore, was estimated from the irrigated acreage served. Estimates of groundwater inflow were taken from Cordova (1964).

Results

The match with recorded data achieved in calibrating BSAM1 to Price River flows at Woodside is portrayed for water flow (Figure 7.2), total salt flow (Figure 7.3), and salt concentration (Figure 7.4). BSAM1 models total salt outflow from the basin by summing loadings from various sources. The amount of salt loading indicated by the model as coming from agricultural lands suggest them to be a major salt source in the Price River Basin. Of the approximately 190,000 tons of salt leaving the basin at Woodside annually during the calibration period, about 76,000 tons or 40 percent originated within the central basin. Model results also indicate that about 3,500 tons originated with ungaged overland flow and pickup by channel processes. These figures agree closely with the estimates given in Chapter VI.

The remaining 72,500 tons of salt originating annually within the central basin are from surface agricultural return flows and groundwater inflows to the Price River. Agriculture is thus an important salt source.

Approximately 114,000 tons of salt were modeled during 1973-1975 as entering the central portion of the basin in approximately 120,000 acre-feet of water (average TDS approximately 700 mg/l), but only about 75,000 acre-feet of water were modeled leaving the basin. Even without any salt pickup in the basin, the outgoing TDS would be about 1100 mg/l--a significant increase from the 700 mg/l--just from concentration effects caused by evapotranspiration. A large portion of this loss is from agricultural crops.

Model results indicate that irrigation efficiencies in the valley are fairly high--

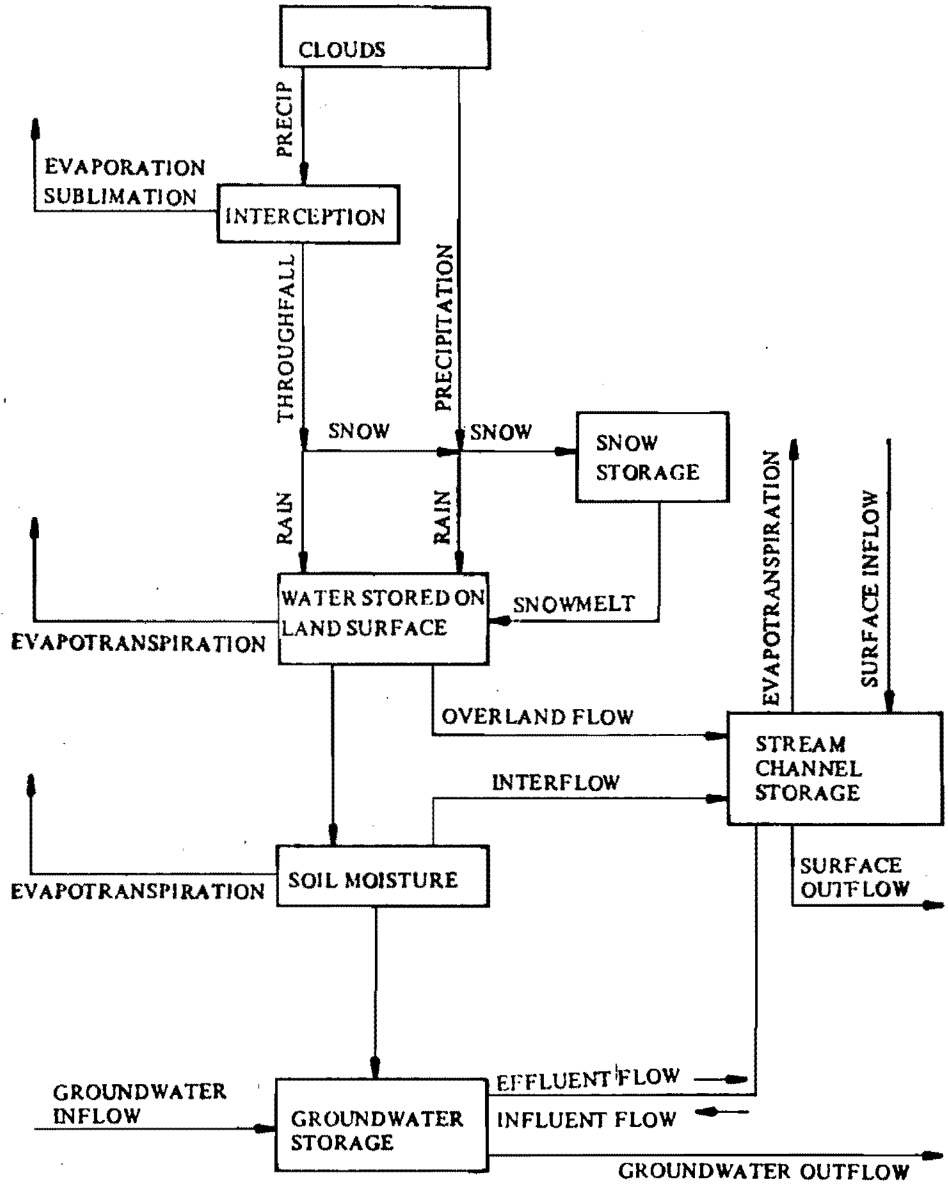


Figure 7.1. Hydrologic system as conceptualized for BSAM (Huber et al. 1976).

Table 7.1. Correlations used to estimate 1973-1975 flows at Heiner.

Month	Equation	Degrees of Freedom	r^2
Jan.	H = 543 + 0.19 (SR) + 3.83 (WC)	5	0.59
Feb.	H = 421 + 0.67 (SR) + 3.1 (WC)	5	0.67
Mar.	H = 907 + 1.06 (SR) + 2.3 (WC)	5	0.993
Apr.	H = 1749 + 1.05 (SR) + 3.2 (WC)	5	0.997
May	H = 137 + 3.95 (BC) + 1.84 (WC) + 0.62 (WR) + 0.98 (SR)	15	0.98
Jun.	H = 137 + 3.95 (BC) + 1.84 (WC) + 0.62 (WR) + 0.98 (SR)	15	0.98
Jul.	H = -1309 - 10.0 (BC) + 7.57 (WC) + 2.16 (WR) + 1.03 (SR)	15	0.95
Aug.	H = -1309 - 10.0 (BC) + 7.57 (WC) + 2.16 (WR) + 1.03 (SR)	15	0.95
Sep.	H = -1309 - 10.0 (BC) + 7.57 (WC) + 2.16 (WR) + 1.03 (SR)	15	0.95
Oct.	H = -166 + 0.96 (SR) + 5.76 (WC)	5	0.95
Nov.	H = 155 + 1.0 (SR) + 4.1 (WC)	5	0.96
Dec.	H = 866 + 0.08 (SR) + 7.4 (WC)	5	0.85

H = Flow at Heiner (AF/mo)

SR = Flow at Scofield Reservoir (AF/mo)

WC = Flow at Willow Creek (AF/mo)

WR = Flow at White River (AF/mo)

BC = Flow at Beaver Creek (AF/mo)

79 percent for conveyance efficiency and 85 percent for application efficiency. The application efficiency seems high, but model calibration was sensitive to this parameter and 85 gave the best match.

The model calibration indicated a lag of about 7 months in deep percolation flows. Agricultural return flows were estimated to have a dissolved solids concentration of about 5350 mg/l. These concentrations appear reasonable in that Desert Seep Wash drains a major portion of the agricultural lands of the basin and typically has dissolved solids concentrations from 2500 to 4000 mg/l. Reduced dilution may account for the difference between Desert Seep Wash concentrations and the 5350 mg/l predicted for agricultural return flows by BSAM1. Another possibility would be that the calibrated 85 percent application efficiency is too high.

Simulation runs were also made to project the effects on flows at Woodside of different management alternatives. The results are summarized in Table 7.2 and highlighted as follows:

1. Ungaged inflow was reduced by 20 percent to determine the effect of upstream detention. The results showed an increase in basin outflow dissolved solids concentrations of about 1.6 percent but a decrease in total salt outflow of about 2.3 percent (Figures 7.5 and 7.6).

2. Irrigation efficiencies were raised by 10 percent to determine the effect of improved irrigation techniques. Results showed an increase in the dissolved solids concentration (TDS) of the basin outflow of 7.1 percent, but a decrease in total salt output of about 7.3 percent (Figures 7.7 and 7.8).

3. Alfalfa (a high water user) on 9200 acres was changed to corn (a low water user), and 1000 acres of phreatophytes were eliminated. Dissolved solids concentrations stayed constant while total salt output rose 5.5 percent (Figures 7.9 and 7.10).

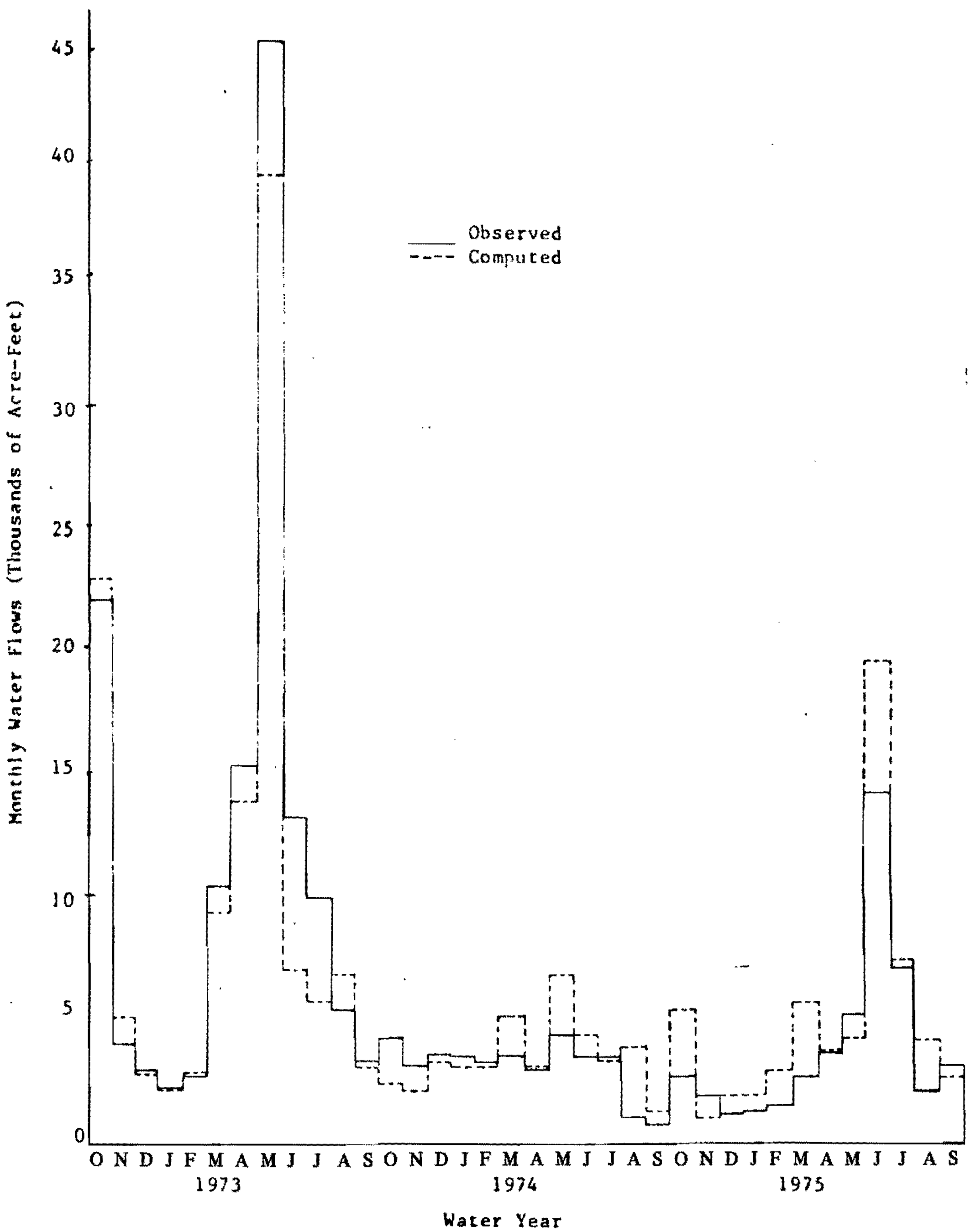


Figure 7.2. Price River BSAM1 simulated water flows at Woodside (1973-1975).

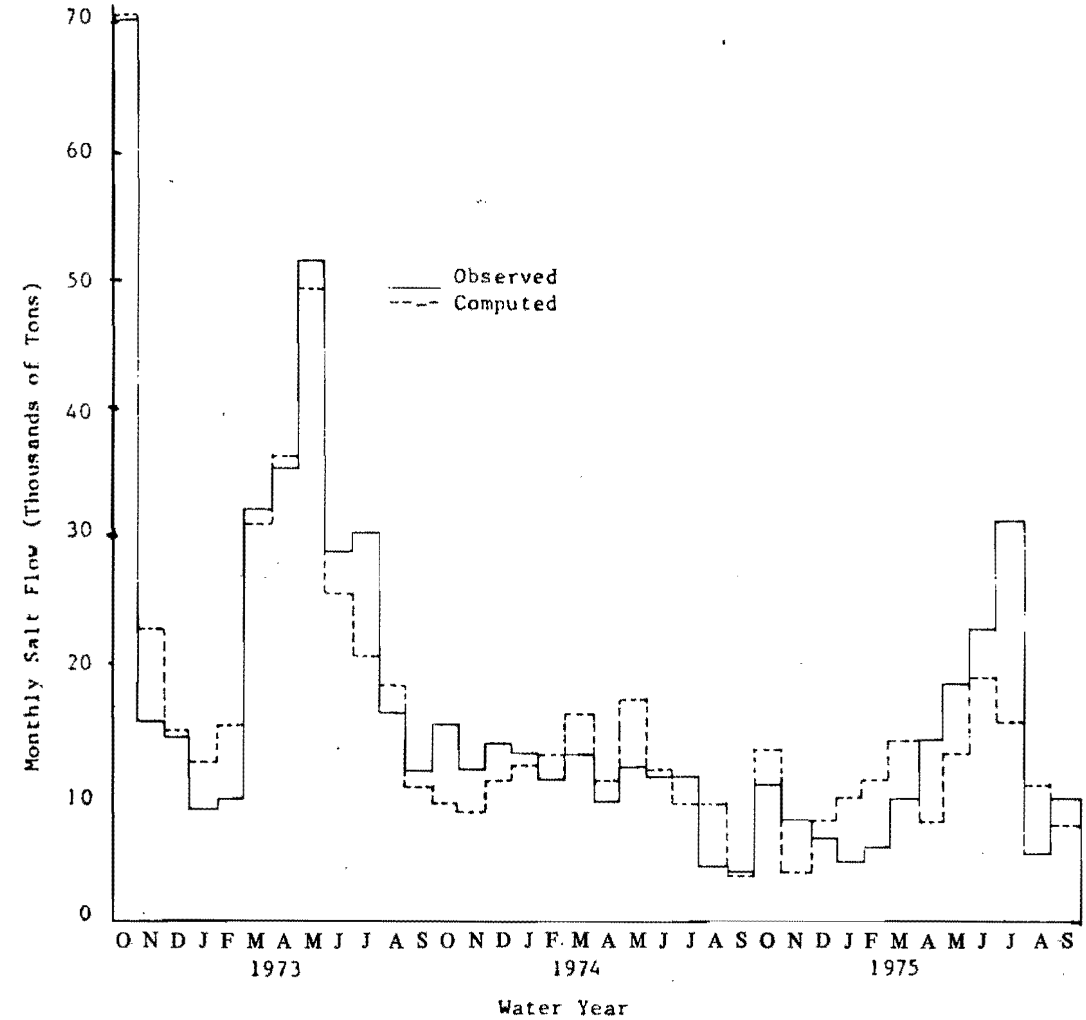


Figure 7.3. Price River BSAM1 simulated salt flows at Woodside (1973-1975).

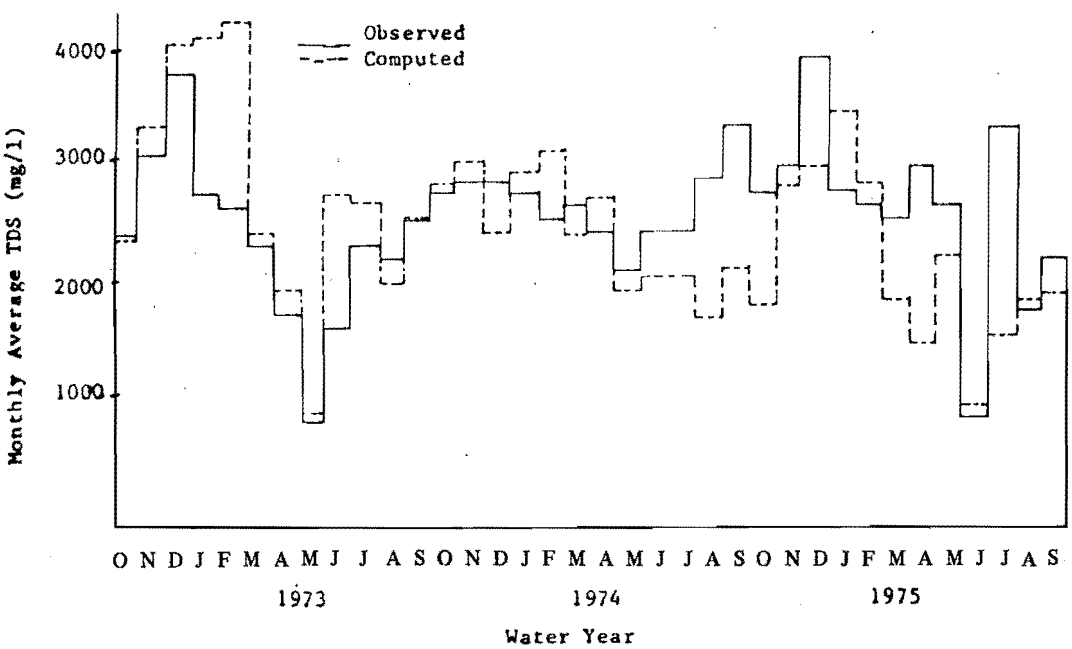


Figure 7.4. Price River BSAM1 simulated salt concentrations at Woodside (1973-1975).

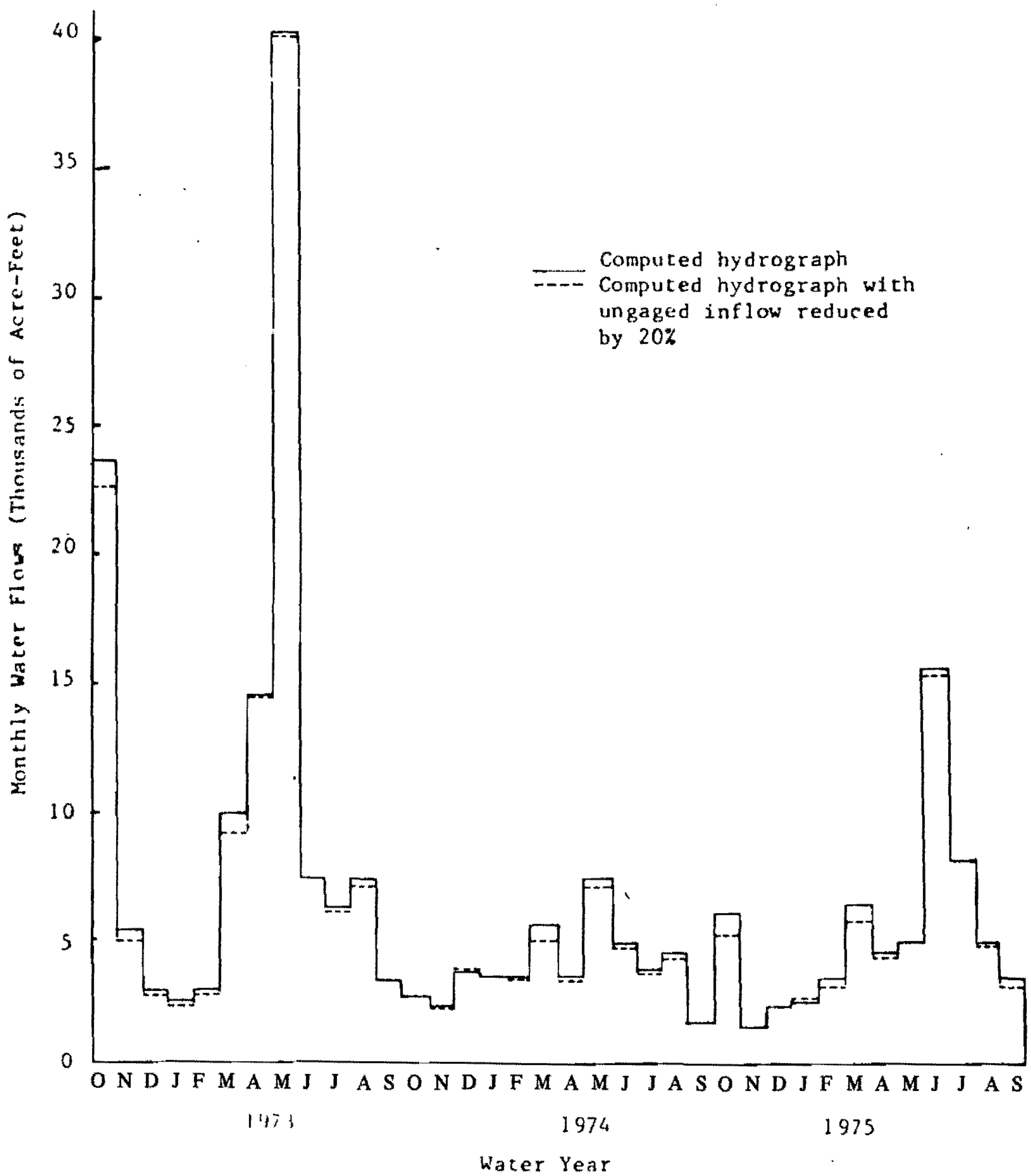


Figure 7.5. Change in Price River hydrograph at Woodside caused by reducing ungaged inflow by 20 percent.

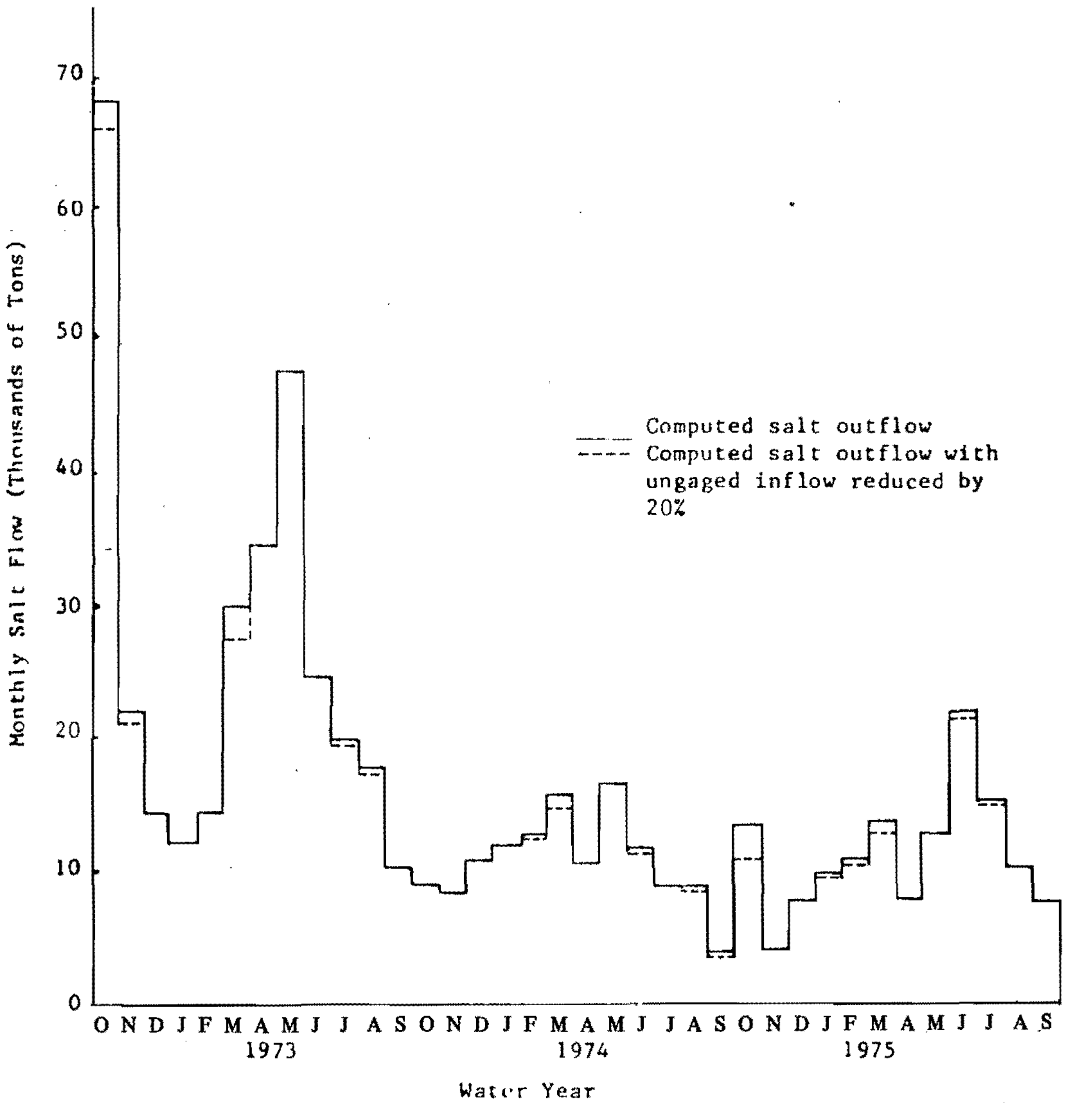


Figure 7.6. Change in Price River salt output at Woodside caused by reducing ungaged inflow by 20 percent.

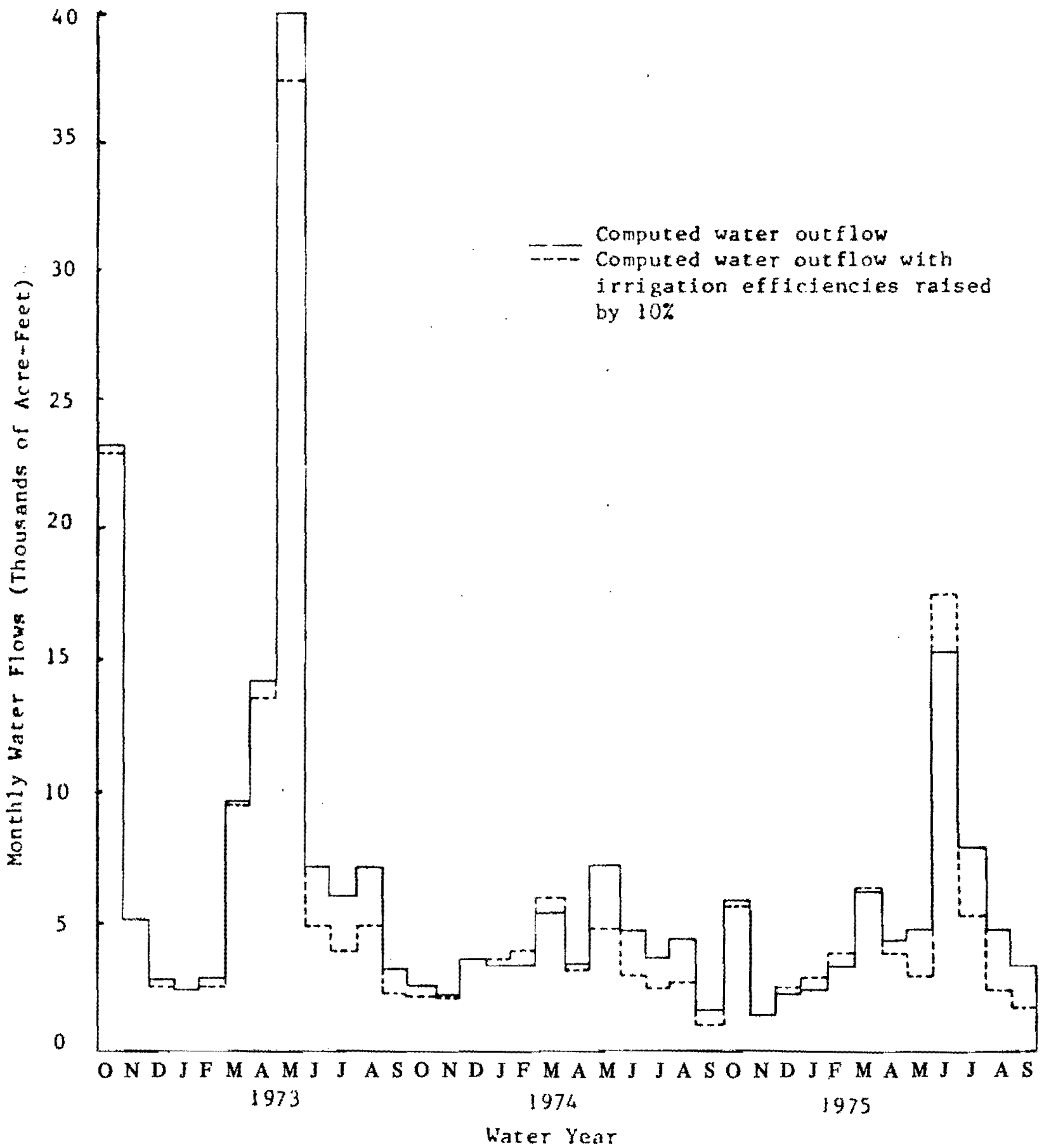


Figure 7.7. Change in Price River hydrograph at Woodside caused by increasing irrigation efficiencies by 10 percent.

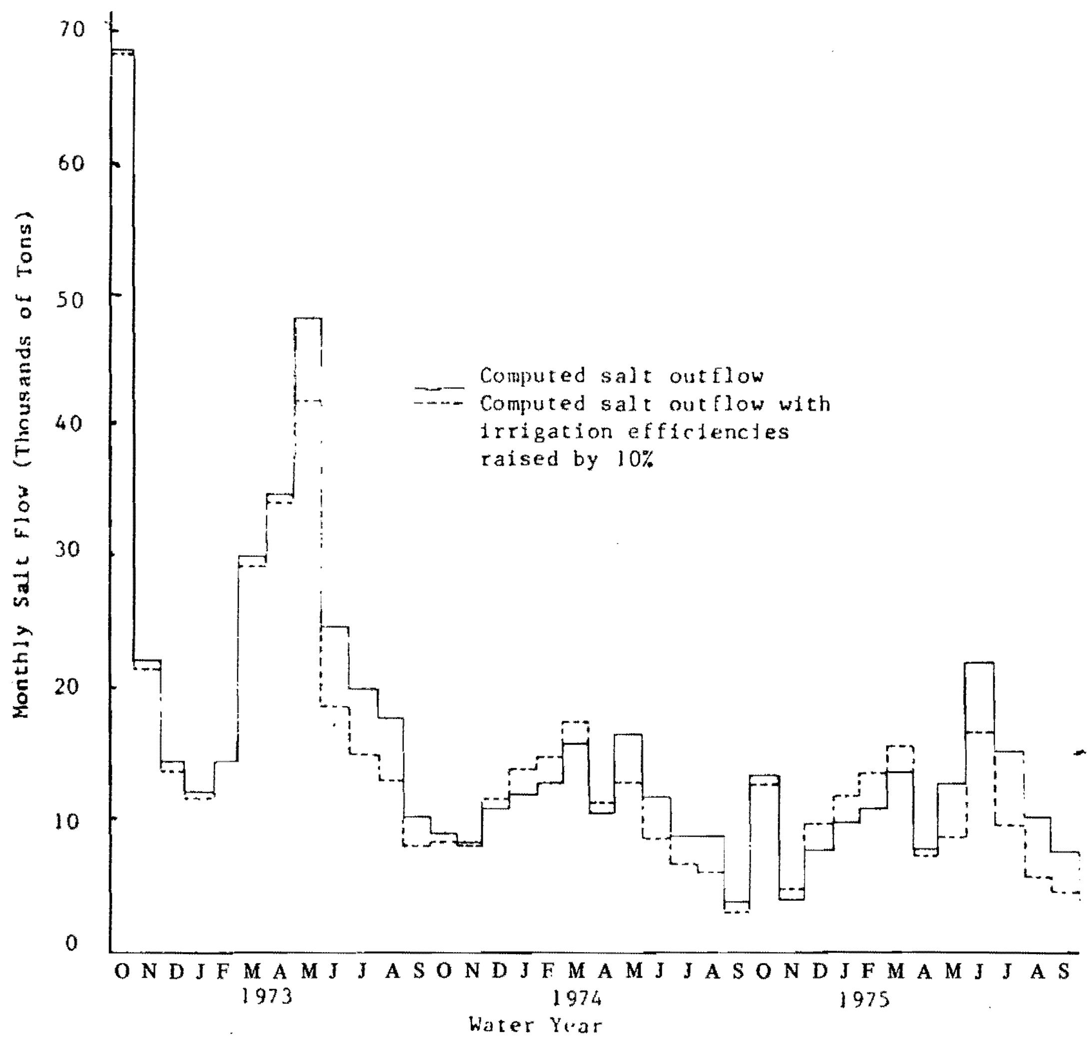


Figure 7.8. Change in Price River salt output at Woodside caused by increasing irrigation efficiencies by 10 percent.

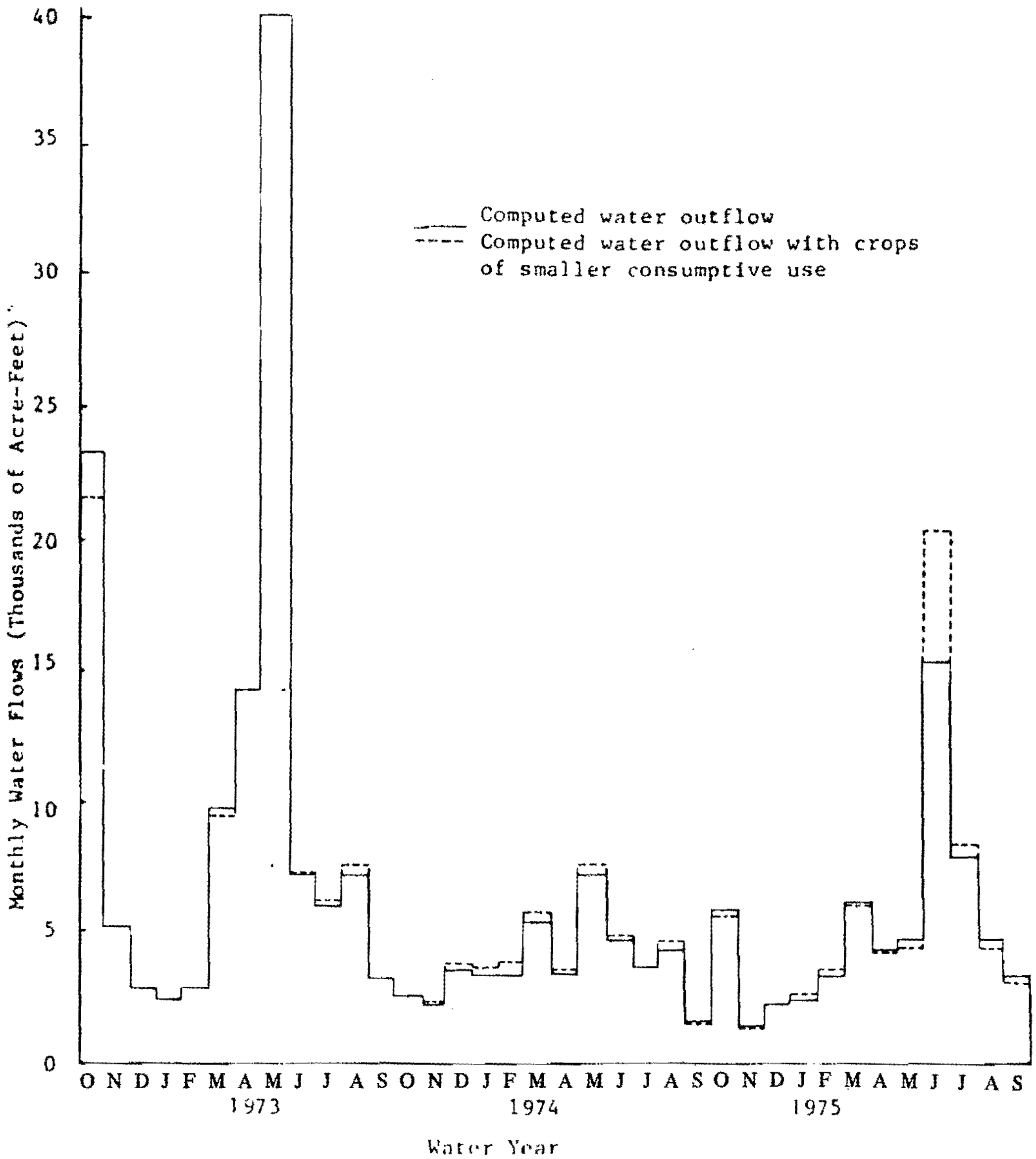


Figure 7.9. Change in Price River hydrograph at Woodside caused by changing to crops with smaller consumptive uses.

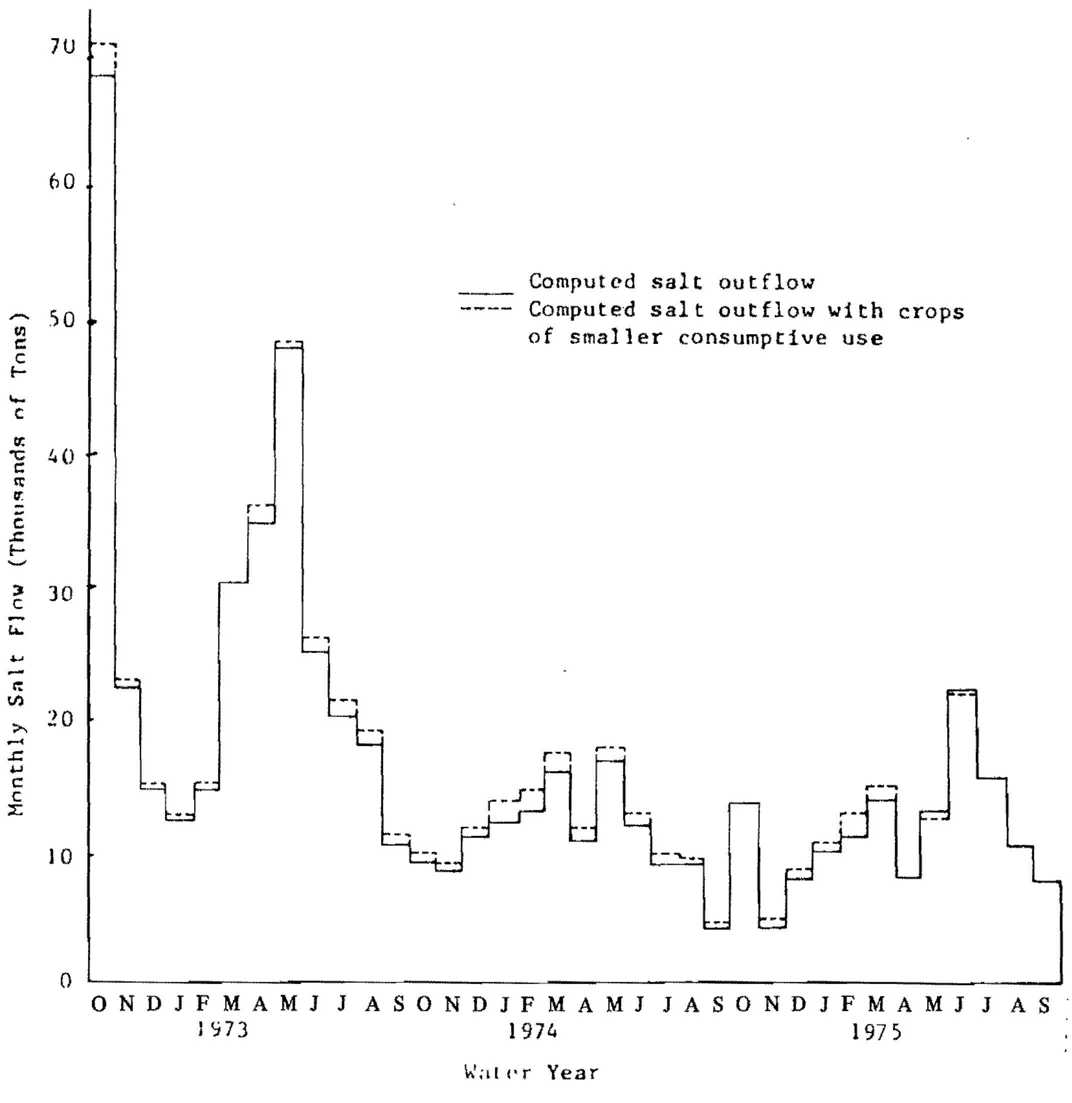


Figure 7.10. Change in Price River salt output at Woodside caused by changing to crops with a smaller consumptive use.

Table 7.2. Price River flows at Woodside with various management options as estimated by BSAM1.

	Computed	Observed	Reduce Ungaged Inflow by 20%	Increase Irrigation Efficiencies by 10%	Plant Crops with Lower C.U.
Water (AF)	76,640	75,780	74,370	68,310	81,180
Salt (tons)	190,640	190,650	186,340	176,760	201,150
TDS (mg/l)	1,830	2,010	1,850	1,960	1,830

CHAPTER VIII

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

Within the Price River valley, salt enters the river as it is carried by overland flow from natural areas, agricultural drainage, and groundwater inflow entering the stream from natural and man-caused sources. Within the river, it is carried by the flow, deposited in the bed sediments, and picked up again by later flows as hydrographs rise and fall.

About 40 percent of the salts leaving the basin annually originate from valley areas, and up to 95 percent of these are associated with agriculturally induced and other groundwater inflows to the stream. The highest observed loading rate was 518 pounds per square mile of catchment daily.

A selected natural channel, Coal Creek, traversing the Mancos Shale wildlands was instrumented and observed during the summer of 1976. Occasional rapid cloud-burst surface runoff was of short duration. Automatic field recording equipment was repeatedly damaged by rocks and debris. Longitudinal salt uptake in the channel was low. Groundwater inflow declined steadily throughout the summer but was of constant quality. The indigenous salts of the bed material were heterogeneous. The largest concentration of entrained soluble salt was approximately 0.7 percent by weight of the channel bed material. Channel efflorescence varied from 18 to 9387 gm/m^2-cm. The largest concentrations occurred in channel depressions and saturated bed material. The lowest concentrations occurred in dry channels with shallow sediment deposits over bedrock. Transport of salt from the soil matrix of the channel bed material to the exposed surfaces of the channel was inhibited by the low hydraulic conductivity of the Mancos Shale derived soils.

Mineral dissolution from the Coal Creek channel material was studied in the laboratory. The time rate of dissolution was low and decreased with time. Turbulent mixing or cyclic drying of the bed material increased the dissolution rates.

Artificial flows were added on two separate occasions into an ephemeral channel within the Coal Creek subbasin. Again, salt uptake tended to decrease exponentially with time. Equation 4.6 describes the accumulated salt loading with an average loading coefficient, K_1, of 2.51 gm/ft^2-$min^{0.5}$.

A hydrosalinity surface runoff model was developed and applied for estimating the salt contributions from overland flow from natural channels. The proportions of the total salt load at Woodside, listed in Table 8.1, were obtained.

A simplified version of the model was applied to the various shale types throughout the Price River Basin. Because most of the salt pickup from surface runoff occurs from the overland and first order channel flows, only these two regimes were included. In addition, the relationship used to represent the salt pickup process in the microchannels (Equation 6.1), while perhaps not representing the process as well as that used in the Coal Creek model (Equation 4.6), could more easily be calibrated to various shale types. The results agree reasonably well with those previously reported by Ponce (1975) and White (1977a).

According to the results obtained by applying BSAM1 approximately 114,000 tons of salt leaving the basin annually at Woodside originate in the mountainous areas. Thus, the loading rate in the mountains (350 square miles) averages 0.51 tons/acre per year. About 76,000 tons per year are derived from the 1,500 square miles of the central basin for a loading rate of 0.08 tons/acre per year. The model further predicts that of this total about 3,500 tons are produced by surface runoff from the nonagricultural

Table 8.1. Estimated salt loading from natural channels.

Natural Salt Source	Percent Total Annual Salt Load at Woodside	
	Extrapolation from the Coal Creek Study Area Assuming all Basin Shales are Undivided	Application of the Coal Creek Model to the Various Basin Shale Types
Overland Flow	5.70	2.10
1st Order Channels	0.74	1.10
2nd Order Channels	0.36	0.36
3rd Order Channels	0.23	0.23
4th Order Channels	0.09	0.09
TOTALS	7.19	3.88

lands. The remainder (72,500 tons) is attributed to return flows from irrigated lands and to groundwater inflows. If this loading is attributed entirely to the 26,000 acres of irrigated farmland in the basin, the agricultural loading rate amounts to 2.81 tons/acre annually.

Conclusions

The study led to the following conclusions on salt loading within the valley floor area of the Price River Basin:

1. Salt loading within the drainage system of the Price River Basin is highly variable with respect to space. The largest amount of salt (approximately 60 percent) originates from the mountainous regions of the drainage. The average salt loading per unit area from the mountains is approximately six times greater than that from the valley floor. In addition to providing the remaining 40 percent of the salt load, the valley floor reduces the flow from the mountains by 37.5 percent. Therefore, the central portion of the drainage increases the salinity concentration by a factor of over 2.5.

2. Storm surface runoff from the valley floor is rapid and of short duration with little significant bank or depression storage.

3. Groundwater inflow concentrations were, in one example, relatively constant and independent of river flow rates.

4. Channel material is heterogeneous with respect to indigenous sulfate, magnesium, calcium, and sodium.

5. Characteristically, initial mineral dissolution is rapid and then declines exponentially.

6. Cyclic wetting and drying, as occurs in ephemeral channels, increases the rate of mineral dissolution.

7. Salt dissolution in natural channels, as in sediment saturation studies, seems to be predominantly diffusion controlled.

8. A linear relationship exists between channel salt pickup and the square root of time.

9. The density of channel efflorescence is highly variable, and the stored salts seem to be a dominant source of salinity in channel flows after long periods of subsurface inflow.

10. Dissolution of salts from fixed channel bed material is not an important mechanism adding salt to stream flow because of 1) the low permeability of the bed materials, and 2) the low salt yielding potential of these materials. Because exposed salts have long since been taken away by their frequent contact with flowing water, the remaining available salt is characteristically low.

11. High salt loading can result from the erosion of new material in both the overland and channel flow regimes. Salt uptake from newly eroded material typically occurs at a rate which decays exponentially as a function of time.

12. Salinity loading in the natural streams traversing the Mancos Shale wildlands is primarily from subsurface inflow. The evaporation of these inflowing waters deposits salt loads on the banks above the water level of flowing streams and often over the entire channel of ephemeral streams. These salt deposits are termed channel efflorescence. Rapid dissolution of the efflorescence occurs in the early stages of a runoff event.

13. The salt load at Woodside from natural overland and channel flows is certainly less than 10 percent, and likely less than 5 percent, of the total. Therefore, substantial reduction in the total salt load from management practices on nonirrigated land is not feasible.

Recommendations

The heterogeneity of the Price River Basin and the spatial and temporal variability of water movement and its carried salt loads are too great for the identification of salt sources and the evaluation of management methods to reduce salt loading to be done effectively without a carefully prepared measurement plan statistically designed to account for system variability. The hydrosalinity models presented in this report provide a conceptual structure that can be used as a foundation for the needed plan. Additional field data collection should support modeling built from this structure. Specific topics deserving study include:

1. The salt contribution from snow on nonirrigated areas, where the snow subsequently melts, percolates through Mancos Shale and discharges into stream channels.

2. Groundwater movement within the basin and of the salt contributions to the Price River from groundwater outflows which are not associated with irrigation.

3. Salt contributions from irrigation return flows, both surface and subsurface, within the basin.

4. The formation and dissolution of efflorescence.

5. The processes of salt-sediment transport with short, sharp hydrographs in ephemeral streams for the purpose of quantitative prediction of movement rates.

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APPENDIX A

CHEMICAL METHODS AND PROCEDURES

College of Eastern Utah Chemistry Department

Methods and procedures for chemical analysis of water samples by the College of Eastern Utah Chemistry Department (Personal Communication with Norm Larsen, 1975).

All samples which were brought in were filtered through Watman GFA paper except samples which contained an excessive amount of debris. These samples were filtered through Watman GFC paper. The filtrate was analyzed by the following procedures:

Table A-1. Methods and procedures, College of Eastern Utah Chemistry Department.

Chemical Constituent	Procedure
pH	pH electrode and meter
EC	Conductivity meter
Cl^-	Potentionmetric titration (Standard Methods 203C)[a]
$SO_4^=$	Gravimetric drying (Standard Methods 156B)[a]
$CO_3^=$, HCO_3^-	Potentionmetric titration (Standard Methods 102)[a]
Ca^{++}, MG^{++}	
Na^+, K^+	Flume emission epctrophotometry
TDS	(Standard Methods 224E)[a]
TSS	(Standard Methods 224A)[a]

[a]Standard Methods 13th Edition, 1971. American Public Health Association, Washington, D.C., pp. 874.

Utah Water Research Laboratory

Methods and procedures for chemical analysis of water samples by the Utah Water Research Laboratory (Personal communication with Pete Cowan, 1977).

All samples were filtered through Watman GFA glass fiber filters. The filtrate was analyzed by the following procedures:

Table A-2. Methods and procedures, Utah Water Research Laboratory.

Chemical Consitutent	Procedure
Cl^-	Potentionmetric titration
$SO_4^=$	Gravitional drying
$CO_3^=$, HCO_3^-	Calculated from pH and temperature[b]
Ca^{++}, Mg^{++}	EDTA titrimetric (Standard Methods)[a]
Na^+, K^+	Flume emission epctrophotometry
TDS	(Standard Methods 224E)[a]
TSS	(Standard Methods 224A)[a]
S_iO_2	Gravimetric (Standard Methods 151A)[a]

[a]Standard Methods 13th Edition, 1971. American Public Health Association, Washington, D.C., pp. 874.

[b]Stumm, W., and J. J. Murgan. 1970. Aquatic chemistry, Wiley-Interscience, New York, pp. 583.

Utah State University
Soils Laboratory

Methods and procedures for chemical analysis of 1:1 soil-water extracts by the Utah State University Soils Laboratory (Personal Communication with Abe Van Luik, 1977).

Soils were sieved through a #20 sieve, rocks excluded by hand. One-hundred grams of soil and 100 ml of distilled H20 mixed by vibration a minimum of 12 hours. After mixing the samples were centrifuged for one minute at 15,000 rpm, filtered through Watman GFA glass fiber filter paper, and the filtrate analyzed by the following procedures:

Table A-3. Methods and procedures, USU Soils Laboratory.

Chemical Constitutent	Procedure
pH	pH electrode meter
EC	Bechman conductivity meter
Cl^-	Potentiometric titration (Standard Methods 203C)[a]
$SO_4^=$	Gravimetric drying (Standard Methods 156B)[a]
$CO_3^=$, HCO_3^-	Calculated from pH[b]
Ca^{++}, Mg^{++}	Atomic adsorption spectrophotometry
Na^+, K^+	Elome emission spectrophotometry

[a]Standard Methods 13th Edition, 1971. American Public Health Association, Washington, D.C., pp. 874.
[b]P. 76 of "Solutions, Minerals, and Equilibrium," (New York: Harper and Row, 1965) 450 p. by Garrels, R. M., and C. L. Clinist.

APPENDIX B

FIELD SURVEY DATA

Table B-1. Price River Basin field study.

Sample Site	Date mo/day/year	Time (military, hrs.)	Field Measurements: Conductivity μmhos	Field Measurements: Temperature °C	Field Measurements: Salinity mg/l	Flow CFS	Na^+ mg/l	K^+ mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Cl^{-1} mg/l	CO_3^{-2} mg/l	HCO_3^{-1} mg/l	SO_4^{-2} mg/l	T.D.S. g/l measured	T.D.S. g/l calculated	T.S.S. g/l	Conductivity (μmhos)	% dev	Settled ph	Shaken ph
							Lab Measurements														
Icelander Creek at Hwy 6 and 50 (Storm Runoff)	7/16/75	16:00 hrs.	--	--	--	> 100 est.	36	6.6	44	31.5	14	19.1	213	122.3	0.35	0.487	65.29	610	-7.62	7.38	7.4
Brushy Sping Creek at Hwy 6 and 50 (Storm Runoff)	7/16/75	16:00 hrs.	--	--	--	< 100 est.	80	14	231	37.5	23	12.1	119	743.8	1.19	1.26	24.23	1480	-0.22	7.2	7.2
Cedar Creek at Route 236	7/17/75	14:45 hrs.	--	27.8°	--	0.21	335	17	250	267	94.8	15.1	139.1	2224.2	3.39	3.342	3.51	3730	-4.48	7.75	7.72
Cedar Creek 1/2 mile above Rte 236	7/17/75	15:10 hrs.	--	26.9°	--	≈ 0.2	390	16	280	199	94.4	10.1	176.3	2236.1	3.3	3.402	3.57	3840	-9.06	7.72	7.88
Cedar Creek 1/2 mile below Rte 236	7/17/75	15:40 hrs.	--	28.1°	--	≈ 0.2	335	16	260	266	94.8	16.1	192.2	2268.2	3.45	3.448	3.59	3720	-7.00	7.8	7.95
Brushy Spring Creek at Hwy 6 and 50	7/17/75	17:20 hrs.	--	28.1°	--	1.9	242	11	200	173	82.0	15.1	192.2	1474.3	2.33	2.39	2.8	2720	-4.45	7.9	7.95
Brushy Spring Creek 1/2 mile below Highway 6 and 50	7/17/75	17:40 hrs.	--	28.3°	--	--	275	13	235	145	80.0	18.1	142.8	1598.3	?	2.508	3.49	2900	-6.63	7.78	8.0
Brushy Spring Creek above Junction Icelander	7/17/75	18:05 hrs.	--	23.3°	--	≈ .01	290	13	250	153	89.6	17.6	178.8	1688.5	2.64	2.69	--	3060	-7.74	7.95	7.95
Below Junction Brushy Spring Creek and Icelander Creek	7/17/75	18:15 hrs.	--	26.4°	--	≈ 0.6	550	21	290	303	102.0	10.1	183.1	2950.1	4.36	4.409	5.02	4700	-5.59	8.0	7.95
Icelander Creek above Junction Brushy Spring Creek	7/17/75	18:25 hrs.	--	26.1°	--	≈ 0.6	570	21	320	307	106	15.6	183.1	2987.3	4.43	4.51	4.85	4780	-3.16	8.0	8.0
Icelander Creek at Hwy 6 and 50	7/17/75	18:49 hrs.	--	23.9°	--	≈ 1.75	540	22	330	300	104	6	250.8	2853.7	4.46	4.407	4.64	4690	-2.19	7.7	7.7
Brushy Spring Creek at Hwy 6 and50	7/25/75	09:00 hrs.	--	21.7°	--	1.4	150	3.8	43	93.7	40.2	20.1	234.9	556.1	0.97	1.142	1.14	1490	-4.29	7.98	8.09
Brushy Spring Creek 1/2 mile below Hwy 6 and 50	7/25/75	09:40 hrs.	--	22.5°	--	≈ 1.0	170	4.1	46	96.4	44.2	27.7	200.1	633.1	1.21	1.222	1.24	1600	-4.88	8.2	8.2
Brushy Spring Creek above Junction Icelander Creek	7/25/75	10:15 hrs.	--	25.6°	--	≈ 0.8	185	4.0	52	97	45.6	15.1	230	677.8	1.25	1.307	1.41	1680	-4.83	8.05	8.17
Icelander Creek below Junction Brushy Spring Creek	7/25/75	10:30 hrs.	--	25.6°	--	≈ 0.9	330	12	144	176	68	15.1	261.2	1475.5	2.5	2.482	2.71	2900	-2.86	7.95	8.03
Icelander Creek above Junction Brushy Spring Creek	7/25/75	10:39 hrs.	--	22.8°	--	.09	870	24	280	444	148	15.1	160.5	4271.5	6.16	6.213	7.05	6500	-7.58	8.27	8.2
Icelander Creek at Hwy 6 and 50	7/25/75	11:00 hrs.	--	22.2°	--	≈ .09	813	20	300	421	142	6	202.6	4014.2	5.97	5.919	6.08	6100	-6.18	8.19	8.19
Cedar Creek 1/2 mile below Route 236	7/25/75	13:10 hrs.	--	29.4°	--	--	330	15	284	271	98.6	5.5	269.7	2275.2	?	3.549	3.64	3700	-6.48	7.85	7.8
Cedar Creek at Route 236	7/25/75	13:30 hrs.	--	28.3°	--	≈ 0.2	345	13	335	281	94.6	10.1	324.6	2239.4	3.57	3.643	3.64	3710	0.38	7.8	7.86
Cedar Creek 1/2 mile above Route 236	7/25/75	13:50 hrs.	--	28.9°	--	.035	445	12.5	323	263	86	10.1	217.2	2256.7	3.66	3.614	3.87	3880	7.73	7.65	7.89
Brushy Spring Creek at Highway 6 and 50	7/29/75	16:35 hrs.	--	--	--	≈ 50	137	13	484	69	26.8	10.5	124.5	1657.5	2.63	2.522	120.88	2630	-2.29	7.82	7.21
Icelander Creek at Hwy 6 and 50	7/29/75	16:55 hrs.	--	--	--	= 50	206	14	368	135	48.2	15.01	144	1784.7	[illegible]	2.715	107.58	2970	-6.33	7.61	7.2
Brushy Spring Creek 1/2 mile below Highway 6 and 50	8/01/75	09:15 hrs.	--	15.6°	--	≈ 0.8	242	9	270	165	78.8	26.7	216.6	1497.0	2.5	2.505	2.83	2760	-0.08	7.8	7.92
Brushy Spring Creek at Hwy 6 and 50	8/01/75	08:55 hrs.	--	15°	--	≈ 1.0	202	9	238	156	74	19.21	211.74	1351.4	2.261	2.28	2.47	2580	-1.78	7.8	7.9
Brushy Spring Creek above Junction Icelander Creek	8/01/75	09:50 hrs.	--	16.7°	--	≈ 0.5	206	12.0	290	166	80	25.8	198.3	1534.5	2.53	2.513	1.75	2800	-2.3	7.9	7.9
Icelander Creek below Junction Brushy Spring Creek	8/01/75	10:05 hrs.	--	17.8°	--	≈ 1.2	400	14.0	270	223	80	19.[illegible]	154.4	2120.9	3.282	3.33	3.83	3550	-0.14	8.1	8.15

Table B-1. Continued.

Sample Site	Date mo/day/year	Time (military hrs.)	Field Measurements: Conductivity μmhos	Temperature °C	Salinity mg/l	Flow CFS	Lab Measurements: Na^+ mg/l	K^+ mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Cl^{-1} mg/l	CO_3^{-2} mg/l	HCO_3^{-1} mg/l	SO_4^{-2} mg/l	T.D.S. g/l measured	T.D.S. g/l calculated	T.S.S. g/l	Conductivity (μmhos)	% dev	Settled ph	Shaken ph
Icelander Creek above Junction Brushy Spring Creek	8/01/75	10:15 hrs.	--	18.6°	--	* 0.8	500	16.7	285	267	90	27.6	188.5	2441.0	4.064	3.84	4.67	4050	1.76	8.05	8.1
Icelander Creek at Hwy 6 and 50	8/01/75	10:50 hrs.	--	20°	--	0.8	485	18.0	287	253	87	19.5	226.4	2362.0	3.738	3.72	4.27	3990	1.23	8.18	8.12
Cedar Creek 1/2 mile below Rte 236	8/01/75	12:30 hrs.	--	26.1°	--	.09	345	13.0	298	275	94	30.3	137.9	2212.6	3.406	3.49	3.84	3600	1.56	8.1	8.02
Cedar Creek 1/2 mile above Rte 236	8/01/75	13:00 hrs.	--	23.3°	--	.03	403	12.0	293	248	82.8	20.11	255.7	2234.0	3.55	3.61	4.95	3750	-1.51	7.92	7.9
Cedar Creek at Route 236	8/01/75	13:25 hrs.	--	26.7°	--	* .06	335	13.0	303	270	92	20.11	184.3	2192.5	3.411	3.5	3.74	?	0.75	8.03	8.0
Brushy Spring Creek at Hwy 6 and 50	8/08/75	09:30 hrs.	--	15.6°	--	.005	540	9	398	305	143	30.3	314.9	2806.0	4.549	4.55	4.71	4720	0.44	7.74	7.9
Icelander Creek below Junction Brushy Spring Creek	8/08/75	10:15 hrs.	--	18.3°	--	.04	1000	18	450	475	152.2	25.2	197.0	4507.6	7.010	6.825	--	7000		8.10	8.32
Icelander Creek above Junction Brushy Spring Creek	8/08/75	10:35 hrs.	--	20°	--	.04	1000	18	437	498	152.0	20.1	244.7	4461.5	6.970	6.831	6.97	6900		8.10	8.14
Icelander Creek at Hwy 6 and 50	8/08/75	10:50 hrs.	--	20.6°	--	.05	870	19	412	448	145.6	35.2	209.3	4071.8	6.600	6.211	6.51	6500		7.89	7.95
Cedar Creek 1/2 mile below Route 236	8/08/75	12:55 hrs.	--	27.2°	--	.07	345	15	280	303	97.0	26.2	187.3	2271.0	3.560	3.524	3.65	3730		7.9	7.95
Cedar Creek 1/2 mile above Route 236	8/08/75	13:25 hrs.	--	26.7°	--	.035	415	14	290	279	84.4	30.2	236.8	2273.1	3.650	3.622	3.50	3880		7.75	7.90
Cedar Creek at Route 236	8/08/75	13:45 hrs.	--	27.6°	--	.06	335	15	290	298	94.0	29.2	169.0	2239.0	3.500	3.469	3.74	3740		8.00	8.05
Brushy Spring Creek at Hwy 6 and 50	8/14/75	09:00 hrs.	4263.2	8.0°	--	.001	550	11	350	367	132.4	26.2	207.5	2890.0	4.570	4.534	--	4670		--	--
Icelander Creek below Junction Brushy Spring Creek	8/14/75	09:55 hrs.	4473.5	18.7°	--	.015	935	22	410	513	150.0	30.2	230.0	4349.1	6.580	6.639	7.01	6600		8.13	8.20
Icelander Creek above Junction Brushy Spring Creek	8/14/75	10:15 hrs.	4123.8	19.5°	--	.02	915	19	360	509	150.0	40.2	205.0	4403.9	6.500	6.602	6.59	6700		8.20	8.21
Icelander Creek at Hwy 6 and 50	8/14/75	10:35 hrs.	4192.5	21.2°	--	.02	813	19	380	474	142.8	39.2	[illegible]	4047.1	6.110	6.114	6.06	6200		8.11	8.18
Cedar Creek 1/2 mile below Route 236	8/14/75	13:15 hrs.	2679.0	28.0°	--	.08	335	15	300	307	94.0	34.2	165.1	2203.2	3.430	3.453	3.68	3640		8.10	8.11
Cedar Creek at Route 236	8/14/75	13:40 hrs.	2966.4	27.0°	--	.07	335	30	310	295	90.0	30.2	207.3	2179.3	3.400	3.479	3.30	3590		7.91	7.98
Cedar Creek 1/2 mile above Route 236	8/14/75	14:30 hrs.	2901.6	28.5°	--	--	415	13	280	275	84.2	25.[illegible]	259.3	2239.0	3.580	3.591	3.74	3800		7.62	7.84
Brushy Spring Creek (upstream)	8/21/75	08:00 hrs.	3720.4	12.3°	--	* .08	600	11	380	384	162.0	44.3	309.9	3032.3	4.850	4.923	4.83	5000		7.80	7.90
Icelander Creek below Junction	8/21/75	08:50 hrs.	4742.2	12.5°	--	≈ .35	935	21	400	506	152.0	37.7	240.4	4308.4	[illegible]	6.600	6.64	6800		8.29	8.29
Icelander (downstream above Junction)	8/21/75	09:10 hrs.	4249.6	13.1°	--	≈ .35	915	23	370	508	148.0	38.2	229.4	4240.5	6.420	6.472	6.51	6700		8.20	8.30
Icelander Creek (upstream)	8/21/75	09:35 hrs.	[illegible]	14.8°	--	≈ .45	813	19	350	[illegible]	142.0	30.2	225.1	[illegible]	6.070	5.975	6.05	6000		8.29	8.31
Cedar Creek (downstream)	8/21/75	12:05 hrs.	2904.6	23.0°	--	.1	[illegible]	14	260	305	94.0	30.2	209.8	2248.0	[illegible]	3.506	3.50	3750		8.30	8.35
Cedar Creek (upstream)	8/21/75	12:30 hrs.	2950.2	24.8°	--	.07	430	12	260	[illegible]	81.0	35.2	326.4	2257.1	[illegible]	3.679	3.69	3920		8.05	8.10
Cedar Creek (Bridge)	8/21/75	13:10 hrs.	2072.4	24.0°	--	* .08	335	15	290	[illegible]	92.0	[illegible]	225.1	[illegible]	3.530	3.195	3.55	3729		8.18	[illegible]

Table B-2. Price River Basin intensive survey 8/26/75.

Sample Site	Date mo/day/year	Time (military hrs.)	Field Measurements: Conductivity µmhos	Field Measurements: Temperature °C	Field Measurements: Salinity mg/l	Field Measurements: Flow CFS	Lab Measurements: Na^+ mg/l	K^+ mg/l	Ca^{2+} mg/l	Mg^{2+} mg/l	Cl^{-1} mg/l	CO_3^{-2} mg/l	HCO_3^{-1} mg/l	SO_4^{-2} mg/l	T.D.S. g/l measured	T.D.S. g/l calculated	T.S.S. g/l	Conductivity (µmhos)	% dev	Settled ph	Shaken ph
Icelander Upstream	8/26/75	11:00 hrs.	6099.0	21.5°		.036	915	17.0	391	478	148.8	25.7	233.3	4325.3	7.240	6.534	7.03	6430		8.10	8.24
Icelander Upstream	8/26/75	16:15 hrs.	6790.0	26.5°			980	20.0	402	524	159.0	20.1	199.5	4719.1	7.480	7.023	7.35	6770		8.46	8.35
Icelander Downstream above Junction	8/26/75	10:15 hrs.	6655.0	16.0°		.0476	1000	18.0	386	541	158.0	17.6	272.7	4687.4	7.740	7.050	7.46	6900		8.27	8.21
Icelander Below Junction	8/26/75	09:45 hrs.	6836.5	14.5°		.022	975	18.0	394	549	157.0	22.6	261.9	4800.1	7.930	7.178	7.69	7040		8.20	8.20
Icelander near Draggerton	8/26/75	08:00 hrs.	2304.8	11.5°		.27	205	12.0	152	172	48.0	21.6	344.8	1083.5	2.060	2.038	2.26	2190		8.15	8.07
Icelander near Draggerton	8/26/75	15:30 hrs.	2268.0	21.0°			190	10.2	120	166	44.2	20.1	327.4	1010.2	1.920	1.858	2.00	2110		8.21	8.20
Brushy Springs Upstream	8/26/75	09:00 hrs.	4954.9	10.5°		.0039															
Price River at Woodside (USGS Gage)	8/26/75	09:10 hrs.	2324.6	17.0°			330	6.8	140	134	40.4	11.7	206.2	1310.2	2.220	2.179	2.44	2510		8.40	8.44
Price River near Wellington (USGS Gage)	8/26/75	10:45 hrs.	2517.2	17.5°			290	7.9	194	143	45.6	20.1	306.9	1320.9	2.390	2.328	2.65	2585		8.53	8.21
Desert Seep Wash near Wellington (USGS Gage)	8/26/75	11:15 hrs.	2480.5	16.0°		33.2	345	6.2	175	122	35.4	10.1	316.7	1277.3	2.170	2.288	3.03	2520		8.51	8.35
Washboard Wash South of Wellington	8/26/75	12:00 hrs.	1858.1	17.0°		23.62	235	5.8	131	82	26.4	12.6	234.9	898.7	1.590	1.626	4.01	1910		8.47	8.15
Desert Seep Wash South of Wellington	8/26/75	13:30 hrs.	6195.0	22.5°		2.74	1125	14.0	228	387	76.0	20.1	306.9	4120.3	6.640	6.277	7.07	6480		8.45	8.40
Desert Seep Wash below Desert Lake	8/26/75	15:00 hrs.	5800.0	25.8°		3.22	1050	15.0	226	383	70.0	25.6	300.8	3922.8	6.250	5.993	6.21	6200		8.55	8.50
Price River at #206 Wellington	8/26/75	10:52 hrs.	1911.8	16.0°		25	242	7.2	199	151	37.0	28.8	238.0	1249.3	2.160	2.152	2.45	2420		8.20	7.96
Miller Creek below Wellington	8/26/75	11:22 hrs.	1679.0	18.0°		10.72	290	7.0	176	128	44.6	35.2	235.5	1209.0	2.090	2.125	3.42	2450		8.35	8.10
Price River 1/4 mile below Miller Creek Junction (Staff Gage)	8/26/75	09:55 hrs.	1992.6	15.0°		25	285	7.3	209	144	44.0	50.3	239.8	1302.4	2.340	2.281	2.64	2620		8.60	8.05
Soldier Creek at Highway 6 and 50 (Staff Gage) #204	8/26/75	09:35 hrs.	1593.7	14.1°		1.3	205	5.7	172	105	32.4	41.2	245.9	948.9	1.710	1.756	1.98	2030		8.50	7.80
Coal Creek at Highway 6 and 50 (Staff Gage)	8/26/75	10:25 hrs.	2532.0	16.2°		3.0	500	8.1	212	202	48.0	43.3	257.5	1987.5	3.250	3.258	3.51	3620		8.48	8.12
Soldier Creek 5 miles above Highway 6 and 50	8/26/75	08:38 hrs.	3312.0	9.8°		.022	705	11.5	157	347	106.2	3.6	385.0	2642.7	4.580	4.358	4.50	4720		8.7	8.5
Coal Creek 5 miles above Highway 6 and 50	8/26/75	07:20 hrs.	1244.7	9.7°		.759	195	5.4	66	102	37.6	40.2	261.2	648.5	1.210	1.356	1.44	1640		8.75	8.40
Deadmans Wash at Highway 6 and 50	8/26/75	13:55 hrs.	1995.0	27.0°		1.513	275	7.5	262	169	40.4	0.0	305.8	1568.6	2.720	2.628	3.00	2830		8.19	7.82
Unnamed Tributary at Highway 6 and 50 in Wellington	8/26/75	13:23 hrs.	1534.7	23.8°		1.72	235	7.3	157	89	24.0	37.7	230.0	939.0	1.640	1.719	1.99	2010		8.68	8.30
Coal Creek at Highway 6 and 50 (Staff Gage #205)	8/26/75	16:32 hrs.	3000.0	26.0°		1.8	525	9.1	207	198	49.4	15.1	255.7	2110.2	3.420	3.369	3.59	3700		8.50	8.49
Price River at Helper	8/26/75	15:55 hrs.	291.5	19.0°		est 50++	8	1.3	52	14	14.0	17.1	169.6	27.6	0.180	0.304	0.26	357		8.21	8.20
Price River at Price	8/26/75	14:50 hrs.	1520.0	25.0°		5.76	150	7.1	160	135	40.6	0.0	301.7	900.8	1.680	1.695	1.75	1930		8.22	8.01
Gordon Creek (1 mile above Price River)	8/26/75	07:30 hrs.	3233.0	6.4°	2000 mg/l	1.781	162	13.0	256	264	66.0	41.3	303.9	1499.9	2.630	2.606	2.87	2740		8.33	8.33
Gordon Creek 5 miles above Price River	8/26/75	09:45 hrs.	5733.0	7.8°	3100 mg/l	.0044	510	17.0	446	362	248.0	13.1	211.3	3084.2	5.290	4.892	5.31	4975		8.60	8.24
Pinnacle Creek 1 mile from Price River	8/26/75	10:47 hrs.	5167.5	12.0°	3000 mg/l	.0896	570	14.0	333	203	90.0	0.0	300.8	2475.6	4.120	3.986	4.28	4200		8.38	8.03
Pinnacle Creek 5 miles upstream from Price River	8/26/75	08:45 hrs.	10293.0	9.3°	6000 mg/l	.0044	1450	35.0	463	641	395.2	35.2	209.7	6191.8	9.800	9.421	9.87	9040		8.57	8.27
Miller Creek at Highway 10	8/26/75	11:25 hrs.	5520.0	18.5°	3150 mg/l	.009	615	12.0	333	320	110.0	36.2	249.2	2883.8	4.940	4.589	4.91	4820		8.17	8.09
Miller Creek on Wattis Road	8/26/75	11:50 hrs.	3216.0	11.5°	1900 mg/l	.136	115	9.6	149	198	77.2	45.3	260.9	960.0	1.840	1.815	1.76	2100		8.71	8.37
Timothy Wash on 155	8/26/75	13:35 hrs.	--	--	3100 mg/l	.028	360	13.0	496	304	26.0	43.8	228.2	2706.4	4.750	4.177	4.61	4320		8.00	7.83
Outlet from Olsen Reservoir	8/26/75	16:15 hrs.	2070.0	18.5°	1100 mg/l	est 10.0	225	5.0	108	82	33.8	32.7	240.9	781.4	1.490	1.508	1.63	1830		8.65	8.28
Miller Creek above Carbon Canal	8/26/75	14:30 hrs.	5348.0	27.5°	3100 mg/l	.0016	590	15.0	357	326	104.0	46.3	253.8	2832.4	4.970	4.583	4.89	4770		8.16	8.11
Drunkards Wash at Highway 10	8/26/75	13:00 hrs.	3774.0	20.0°		6.745	275	9.7	371	197	34.2	0.0	276.2	2091.2	3.380	3.254	3.46	3315		8.35	8.00
Cedar Creek near Mohrland rd.	8/26/75	11:00 hrs.	713.0	18.0°		.2841	11	3.3	65	71	13.0	29.2	194.0	223.9	0.550	0.610	0.63	777		8.69	8.15
Cedar Creek at "Site A" (upstream)	8/26/75	10:00 hrs.	3680.0	18.0°		.009	415	11.3	330	254	83.4	27.7	235.5	2296.6	3.860	3.653	4.02	3900		8.00	8.00
Cedar Creek at "Site B" (middle)	8/26/75	09:30 hrs.	3537.5	14.0°		.142	335	13.0	327	283	95.0	26.2	208.1	2246.8	3.690	3.534	3.88	3750		8.16	7.86
Cedar Creek at "Site C" (downstream)	8/26/75	11:40 hrs.	3885.0	22.5°		.023	345	15.0	329	287	93.0	26.1	213.0	2298.6	3.940	3.612	3.87	3825		8.21	7.86
Cedar Creek at Cleveland Canal	8/26/75	08:45 hrs.	3082.0	11.5°		.0238	415	15.2	349	355	114.0	32.7	168.4	2680.5	4.420	4.130	4.51	4340		8.40	7.95

Table B-3. Price River profile survey.

Location	Time	Date	Discharge (cfs)	Conductivity μmhos at 25°C	pH	Temp. °C	TSS mg/l	TDS mg/l	T. Hard mg/l at $CaCO_3$	CA^{++} mg/l	Mg^{++} mg/l	NA^{+} mg/l	K^{+} mg/l	SiO_2 mg/l	CL^{-} mg/l	$SO_4^{=}$ mg/l	River Miles
Castle Gate	0800	10-19-76	31.68	297	7.30	10.6	17.8	262	439	77.2	59.8	10	4	3.4	9.7	86	0
Golf Course		10-19-76			6.85		3.4	874	549	166.4	32.3	60	7	14.0	33.4	354	6.4
Above Price	0930	10-19-76	3.80	2195	7.85	3.9	4.1	1976	1044	249.6	102.1	160	10	9.3	24.5	990	9.6
Below Price	1020	10-19-76	5.37	2320	7.85	4.4	7.4	2074	1024	265.2	87.8	160	9	8.9	17.8	1060	11.6
Above Wellington	1100	10-19-76	14.73	3128	7.85	6.0	11.2	2866	1327	400.0	79.5	260	12	8.3	37.0	1665	16.6
Below Wellington	1140	10-19-76	22.62	3248	7.85	15.0	56.1	3056	1312	372.4	92.6	340	12	8.5	26.0	1725	21.6
Below Miller	1450	10-19-76	23.14	3505	8.65	10.0	13.7	3210	1288	416.0	60.3	330	12	6.2	86.7	1810	26.4
Mounds	1540	10-19-76	20.35	3547	--	10.0	14.6	3212	1288	404.0	67.6	320	13	4.4	56.1	1915	32.4
Cottonwood	1735	10-19-76	51.00	3996	8.65	6.1	11.7	3570	1257	261.6	146.6	500	14	0.8	52.0	2300	44.4
Sulpher	1230	10-20-76	38.24	3417	7.90	16.1	46.4	3480	1337	318.8	131.3	460	14	0.3	47.2	1950	51.4
Coon Springs	0915	10-21-76	50.75	4026	8.20	8.2	12.7	3526	1330	368.4	99.4	500	14	1.1	53.3	2000	61.0
Silvagni	1050	10-21-76	35.80	4053	8.65	9.4	19.1	3618	1346	338.8	121.3	500	14	0.5	54.8	2325	70.0
Woodside	1145	10-21-76	37.91	4366	8.50	9.3	42.1	3600	1351	358.4	110.6	540	14	0.7	66.6	2300	78.8

APPENDIX C

COAL CREEK FIELD DATA

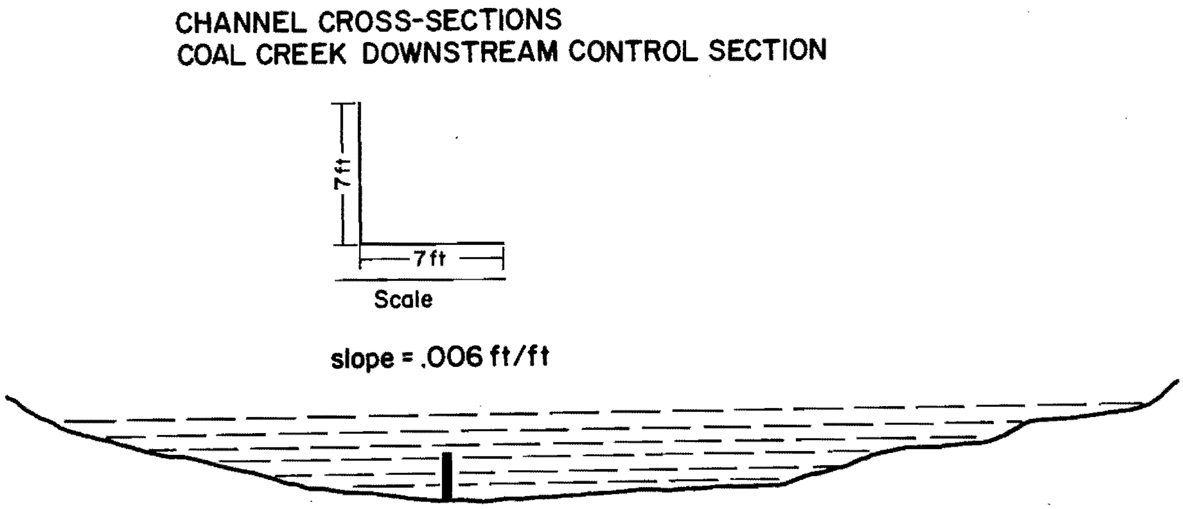

Figure C-1. Channel cross sections, Coal Creek downstream.

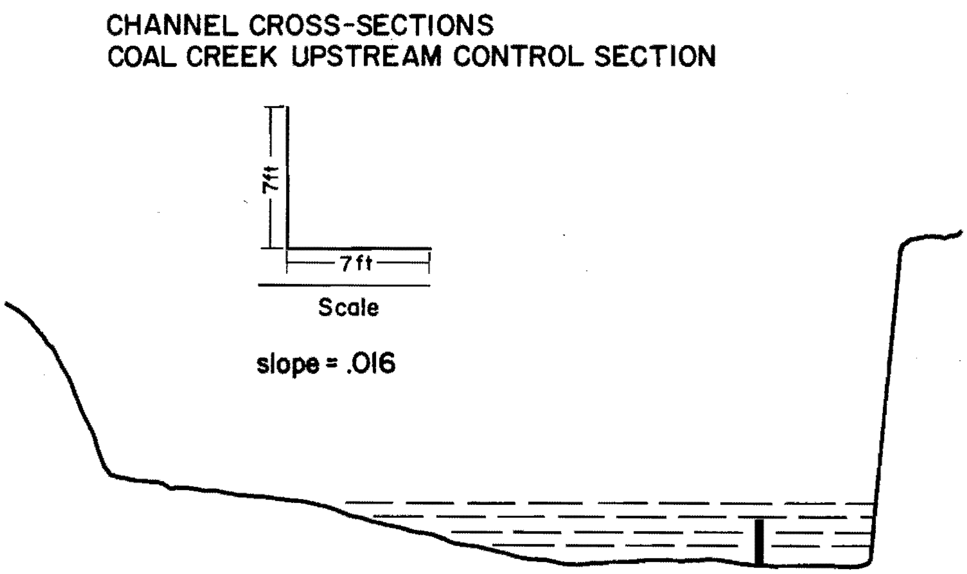

Figure C-2. Channel cross section, Coal Creek upstream.

Table C-1. Coal Creek conductivity profile.

Site Location in miles from Upper Site	Conductivity µmhos/cm @ 25° C	Temperature °C	pH	Measured Total Alkalinity mg/l as $CaCO_3$
8.2	4630	21.5	8.56	273
7.5	3678	23.0	8.40	287
7.1	3382	21.0	8.40	284
6.3	3172	24.0	8.40	279
5.6	3044	21.7	8.52	298
4.3	3363	22.0	7.50	339
3.8	2642	18.0	7.81	343
2.2	798	24.5	8.41	291
Tributary receiving interflow	21732	25.0	8.00	590
1.4	804	23.0	8.40	266
Irrigation Ditch	749	22.0	8.58	267
0.3	759	22.5	8.60	269
4.2	2892	22.5	8.36	336

Table C-2. Coal Creek water quality.

Observation Location	Date Sample Taken	Field Temp°C	Field pH	Conductivity at 25°C umhos/cm	TSS mg/l	Total Alkalinity mg/l as $CaCO_3$	TDS mg/l	Total Hardness mg/l as $CaCO_3$	Ca^{++} mg/l	Mg^{++} mg/l	Na^{+} mg/l	K^{+} mg/l	Li^{+} mg/l	SiO_2 mg/l	Cl^{-} mg/l	SO_4^{-2} mg/l	Flow (cfs)	Staff Gage (feet)
Lower Site	2/21/76	0.1	8.1	911.0	162	360.6	602	380	29.4	28	84	3.8		7.4	17.0	175		
Lower Site	2/25/76	0.1	8.3	722.0	227	307.5	470	304	26.4	21	70	3.5		6.3	14.0	125		
Upper Site	3/4/76	0.1	8.4	837.0	100	358.3	548	344	28.8	24	76	3.2		7.4	16.0	160		
Lower Site	3/4/76	0.4	8.4	2576.80	960	298.9	2028	767	54.4	59	360	4.8		7.3	41.0	1125		
Upper Site	3/6/76	0.0	8.3	911.0	525	383.8	580	360	31.6	24	81	2.9		7.9	15.0	150		
Upper Site	3/10/76	10.0	8.3	282.2	5272	173.4	238	150	15.8	9	40	2.8		5.0	8.5	50		
Lower Site	3/10/76	10.0	8.2	1128.8	1144	225.4	740	342	28.2	24	109	3.9		6.1	20.0	380		
Upper Site	3/13/76	0.1	8.1	707.0	217	312.0	476	244	20.2	17	100	5.0	0.1	7.0	15.0	138		
Lower Site	3/13/76	0.4	8.4	1306.0	403	279.8	884	393	33.6	27	130	4.0	0.1	7.1	21.0	432		
Upper Site	3/17/76	0.5	8.3	423.0	22510	247.2	212	212	18.2	15	44	4.0		5.4	8.5	72		
Lower Site	3/17/76	12.4	8.5	1197.0	2734	202.9	722	342	29.4	23	130	3.8		6.5	17.0	356		
Upper Site	3/20/76	0.4	8.3	727.0	796	299.5	432	261	27.2	15	86	4.0		7.2	13.0	140		
Lower Site	3/20/76	1.2	8.3	1422.0	2044	242.3	888	429	35.8	30	160	4.0		7.0	23.0	480		
Upper Site	3/24/76	0.6	8.5	791.0	2160	277.0	464.0	261	26.4	16	100	4	0.1	6.8	12.0	117		
Lower Site	3/24/76	12.0	8.4	1581	715	280.0	1104	458	37.6	32	280	5	0.1	7.6	24.0	564		
Upper Site	3/27/76	5.8	8.3	714	1196	267.0	492	272	26.4	17	105	4	0.1	6.5	15.0	144		
Lower Site	3/27/76	7.2	8.5	1520	2009	262.0	1112	489	41.0	34	290	6	0.1	8.0	2.1	538		
Upper Site	3/31/76	5.4	8.5	708	1875	307.0	490	278	27.0	17	66	2	0.1	8.0	11.0	126		
Lower Site	3/31/76	11.0	8.5	1794	326	289	1408	528	37.6	41	210	5	0.1	8.5	30.0	720		.28
Upper Site	4/2/76	7.4	8.5	868	1658	312	514	297	26.2	20	68	4	0.1	7.8	9.1	125		
Lower Site	4/2/76	12.3	8.5	1729	553	292	1238	490	33.8	39	240	6	0.1	8.2	27.0	636		.29
Upper Site	4/9/76	3.2	8.4	748	1931	311	444	302	27.6	20	73	2		8.2	14.0	125		
Lower Site	4/9/76	3.5	8.5	1859	923	311	1266	571	40.8	44	210	6		8.8	28.0	726		.53
Upper Site	4/14/76	6.0	8.4	691	3254	274	448	279	31.0	15	63	5		7.0	12.0	132		
Lower Site	4/14/76	12.0	8.5	1474	550	264	1008	420	35.6	29	170	6		7.6	23.0	530		.45
Upper Site	4/17/76	8.5	8.4	851.4	3668	263	544	324	36.0	17	80	5		7.3	15.0	198		
Lower Site	4/17/76	9.7	8.4	1806.1	4787	245	1248	491	41.8	34	220	7		7.2	25.0	684		.58
Upper Site	4/20/76				2670	289.4	452	265	26.0	16	78	5		8.3	13.0	119		
Lower Site	4/20/76				1111	258.8	1100	444	32.4	34	200	7		7.3	27.0	580		
Upper Site	4/24/76	4.0	8.4	763.6	2024	286.7	448	291	29.6	17	66	4		8.5	12.0	120		.24
Lower Site	4/24/76	6.5	8.5	1935.6	212	276.1	1454	582	43.4	44	260	8		7.9	27.0	808		.33
Lower Site	5/1/76	11.1	8.6		2.52	310	2392	854	51.8	71	440	8		10.0	46.0	1440	.283	
	5/1/76	15.6	8.6	2889.2	52.9	332	2246	823	40.8	74	430	8		11.0	39.0	1265	.138	
Laterial Inflow Below Middle Site	5/1/76	7.8	7.75	3900.0	0.85	346	2820	964	50.2	86	560	8		11.0	3.9	1695		
Middle Site	5/1/76	24.4	8.6	2827.0	4.01	328	2172	784	50.8	64	420	8		12.0	6.8	1315	.233	
Spring	5/1/76	13.3	7.95	2730.0	5.38	366	2112	801	46.2	68	380	8		12.0	2.2	1225		
Coal Creek at Spring	5/1/76	23.9	8.6	2805.0	8.35	363	2238	789	44.6	68	400	8		11.0	1.8	1215		
2nd Large Cottonwood Tree West	5/1/76	25.6	8.9	4672.8	78.1	323	4038	1226	49.8	117	720	13		9.6	67.0	2470		
Ist Large Cottonwood Tree East																		

Table C-2. Continued.

Observation Location	Date Sample Taken	Field Temp°C	Field pH	Conductivity at 25°C umhos/cm	TSS mg/l	Total Alkalinity mg/l as $CaCO_3$	TDS mg/l	Total Hardness mg/l as $CaCO_3$	Ca^{++} mg/l	Mg^{++} mg/l	Na^+ mg/l	K^+ mg/l	Li^+ mg/l	SiO_2 mg/l	Cl^- mg/l	SO_4^{2} mg/l	Flow (cfs)	Staff Gage (feet)
At Power Line Below 1st Ranch House	5/1/76	23.3	8.9	2891.2	22.8	268	2468	957	44.8	88	370	11		9.3	61.0	1515		
	5/1/76		8.7		4.06	283	2476	872	45.8	77	440	10		11.0	49.0	1475		
Upper Site	5/1/76		8.6		819	276	474	276	22.2	20	65	4		8.2	14.0	130		
Upper Site	4/27/76	10.4	8.3	838.0	1560	286.7	504	276	24.8	18	64	2		7.5	14.0	131		.39
Lower Site	4/27/76	17.0	8.4	2487.0	52.9	260.7	1926	683	41.4	57	260	6		8.2	40.0	1120		.34
Upper Site	5/5/76	12.0	8.4	737.5	565	255.4	440	264	21.4	19	54	2		6.8	14.0	112		
Lower Site	5/5/76	16.3	8.5	3265.1	15.1	252.5	2594	869	47.8	76	450	8		8.6	53.0	1500		.29
Upper Site	5/8/76	10.0	8.4	698.4	1114.0	274.8	456	280	23.4	20	53	2		7.6	12.0	100		.39
Lower Site	5/8/76	13.0	8.4	2094.4	431	271.9	1562	589	49.8	41	230	6		8.2	32.0	446		.39
Upper Site	5/12/76	15.0		748.2	437		544	516	32.2	43	60	2		8.1	13.0	124		
Lower Site	5/12/76	20.5		2940.2	4.32		2376	1634	160.0	100	500	6		8.8	48.0	1324		.30
Upper Site	5/19/76	16.2	8.4	727.3	252	258.5	526	522	65.4	23	63	2		7.9	13.0	105		
Lower Site	5/19/76	21.2	8.1	2164	8.20	270.9	1684	1212	76.4	100	100	6		8.2	35.0	1088		
Upper Site	5/22/76	18.5		689.7	790.0		538	266	22.6	18	18	2		7.9	11.0	103		
Lower Site	5/22/76	21.2		1082	2093		672	274	30.8	14	75	3		8.2	12.0	250		
Upper Site	5/26/76	18.7	8.32	687.0		255.5												
Lower Site	5/26/76	26.0	8.26	1331.4		241.0												
Upper Site	5/29/76	10.1	8.4	661.5	253	282.2	398	256	22.0	18	53	3		6.9	12.0	98		
Lower Site	5/29/76	12.0	8.4	1904.2	139	256.5	1348	567	33.6	48	215	4		8.3	30.0	696		
Upper Site	6/3/76	19.0	8.6	681.6		259.7												
Lower Site	6/3/76	25.2	8.5	2191.9														
Spring	7/9/76	14.8	6.4	2734	3.0		204	820	183.2	88	310	8		11.7	1.0	1100	.086	
Upper Site	7/9/76	12.8	8.1	826	13.4		274	295	48.4	42.3	70	5		7.0	13.0	152	.36	.155-
Middle Site	7/9/76				0.7		1996	812	153.2	104.2	230	8		10.7	33.0	1865		3.78
Spring	7/15/76	13.0	7.9	2862	2.3		8182	768	91.6	131.0		10		10.7	41.0	2100	.086	
Upper	7/15/76	27.0	8.65	818	3.4		6526	283	36.8	46.4	60	5		7.0	15.0	199	.45	.17
Middle	7/15/76	25.5	—	3050	20.4		1797	840	143.2	86.8	230	8		11.2	0.5	1260		3.745
Spring	7/22/76	15.3	7.20	2612	3.7		1882	808	176.8	88.9	260	8		11.6	1.0	980	.086	
Upper	7/22/76	13.3	8.95	776	41.3		312	291	73.2	26.2	70	5		7.7	13.0	108	.73	.21
Lower	7/22/76	29.2	8.20	1465	169.0		842	461	100.0	51.3	135	6			23.0	480	.23	.34
Middle	7/22/76	26.5	8.15	1629	431.0		1010	509	113.2	54.9	135	7		9.4	23.0	480		3.81
Upper	7/17/76	20.3	8.8	820	39.9		258	291	43.2	44.5	65	6		7.6	20.0	125	.39	.16
Middle	7/27/76	20.3	8.6	2547	16.6		1592	735	153.2	85.5	210	9		9.3	24.0	900		3.77
Lower	7/27/76	24.0	8.3	2367	24.5		1784	655	150.0	68.0	210	9		9.3	36.0	890	.119	.32
Upper	7/28/76	18.0	8.7	893	92.2		476	299	46.8	44.2	95	6		8.0	15.0	159	.316	.15
Middle	7/28/76	20.0	8.5	2895	54.3		1932	792	150.0	101.3	260	8		10.2	31.0	1200	.148	3.76
Lower	7/28/76	23.0	8.65	3018	613.0		1924	760	130.0	105.7	295	10		11.1	46.0	1310	.058	.315
Spring	7/29/76	12.0	7.15	2802	1.5		1848	865	180.0	100.8	280	8		9.3	1.0	1050	.09	
Upper	8/5/76	26.0		939	30.4		302	307	83.2	24.1	80	6		9.9	14.0	161		.175
Spring	8/5/76	13.0	7.30	3026	4.4		1722	857	196.8	88.7	185	8		8.8	0.5	925	.079	
Middle	8/5/76	27.0	8.60	1340	137.0		616	412	106.8	35.2	120	8		11.9	20.0	326	1.073	3.92
Lower	8/5/76	27.0	8.60	1413	879.0		694	420	153.2	9.0	90	9		11.2	21.0	436	.721	.465

Table C-2. Continued.

Observation Location	Date Sample Taken	Field Temp°C	Field pH	Conductivity at 25°C umhos/cm	TSS mg/l	Total Alkalinity mg/l as $CaCO_3$	TDS mg/l	Total Hardness mg/l as $CaCO_3$	Ca^{++} mg/l	Mg^{++} mg/l	Na^+ mg/l	K^+ mg/l	Li^+ mg/l	SiO_2 mg/l	Cl^- mg/l	SO_4^{2} mg/l	Flow (cfs)	Staff Gage (feet)
Upper	8/12/76	10.0	8.70	1042	5.1		380	331	76.8	33.8	80	6		7.8	11.0	152		.13
Spring	8/12/76	13.0	7.35	2943	17.2		1908	840	190.0	88.7	320	8		12.0	1.5	1025	.083	
Middle	8/12/76	21.0	8.35	3025	0.32		1970	865	210.0	82.6	225	9		11.9	30.0	1225	.128	3.75
Upper	8/19/76	25.6	8.65	982	2.8		784	357	64.8	47.4	96	7		8.1	5.2	292		.135
Spring	8/19/76	16.6	7.35	2733	2.9		2302	867	282.8	38.9	290	9		12.5	4.1	1270		
Middle	8/19/76	26.0	8.25	2832	0.7		2252	806	84.8	144.3	320	9		11.7	44.0	1080		3.70
Upper	8/27/76	8.9	8.65	1005	34.0		640	327	64.4	46.4	90	7		9.7	18.0	177		Washed out
Spring	8/27/76	13.0	7.30	2820	0.5		2120	857	182.0	97.7	300	9		12.2	2.1	1145	.064	
Middle	8/27/76	15.0	8.40	2688	33.0		1986	857	151.6	116.2	260	10		10.9	36.0	1020		Bent
Lower	8/27/76	10.5	7.35	1906	245.0		1572	857	246.4	58.6	120	12		8.9	18.0	830		Bent
Upper	9/2/76	21.7	8.65	1103	11.6			176	24.4	28.0	90	7		7.8	3.5	226	.061	Lost
Spring	9/2/76	13.6	8.05	2780	0.8			412	54.8	66.9	250	8		11.3	1.0	1060	.067	
Middle	9/2/76	15.6	8.55	2996	0.1			412	53.2	67.8	260	10		11.5	1.8	1740	.125	3.79
Upper	9/8/76	20.0	8.45	954	3.1		674	145	16.8	25.0	75	6		6.9	18.0	204	.179	.04
Spring	9/8/76	18.3	7.70	2851	1.3		2110	416	87.2	48.1	260	10		11.5	1.8	1740	.067	
Middle	9/8/76	25.0	8.40	1922	6.3		1400	278	75.6	21.6	160	10		9.2	26.0	680	.225	3.70
Lower	9/8/76	23.9	8.40	1670	2.3		1370	318	77.2	30.4	100	13		8.0	15.0	715	.186	.25
Upper	9/15/76	21.1	8.30	353	78.1		276	87	14.4	12.4	50	4		7.8	8.1		.636	.14
Spring	9/15/76	17.5	7.75	1786													.061	
Middle	9/15/76	21.1		1061	39.6		726	308	68.8	33.1	90	6		7.7	21.0		.955	3.82
Lower	9/15/76	17.3	8.65	985	2.2		630	164	33.2	19.7	80	6		7.6	16.9		.946	.38
Upper	9/24/76	16.2	8.45	964	21.7		640	135			95	6		7.9	17.8	184	.481	.13
Spring	9/24/76	15.3	8.15	2730	0.42		2054	462	33.2	92.1	580	8		12.0	6.2	1120	.064	
Middle	9/24/76	18.1	8.50	2184	2.2		1592	337	91.6	26.3	460	8		10.3	34.0	840	.236	3.70
Lower	9/24/76	14.7	8.55	3086	1.4		2192	375	124.8	15.3	680	10		10.7	49.0	1375	.05	.17
Upper	10/1/76	15.5	8.55	917	19.5		678	178	35.6	21.6	95	6		7.5	17.0	160	.094	.025
Spring	10/1/76	13.3	7.90	2736	2.5		2266	803	212.4	66.1	620	8		11.5	8.2	1155	.058	
Middle	10/1/76	14.3	8.45	2413	16.6		1856	370	48.0	60.8	570	8		10.4	22.5	875	.277	3.69
Lower	10/1/76	9.2	8.65	2602	2.8		2114	769	96.0	128.6	590	9		10.4	43.0	1140	.256	.180
Upper	10/8/76	1.9	8.65	947	1.9		700	347	86.8	31.6	90	6		8.4	4.2	180		.008
Spring	10/8/76	13.9	7.65	2825	7.6		2220	812	194.0	79.5	310	8		11.9	7.5	1175	.055	
Middle	10/8/76	19.4	8.4	2521	2.2		1956	713	155.6	78.8	300	9		10.8	15.5	995		3.70
Lower	10/8/76	19.4		2897	1.7		2388	792	182.0	81.9	360	10		10.8	48.0	1390		.19
Upper	10/15/76	15.7	8.65	1001	1.6		692	390	101.3	33.3	95	7		7.9	23.5	196	.161	.10
Spring	10/15/76	12.3	7.95	2792	2.4		2162	829	138.8	117.2	320	12		11.1	40.8	1175	.05	
Middle	10/15/76	7.9	8.45	2868	5.8		2272	844	204.0	81.2	350	10		11.0	39.8	1280	.059	3.7
Upper	10/20/76	7.8	7.75	1107	29.5		760	459	136.8	28.4	110	8		8.5	23.0	234	.111	.08
Spring	10/20/76	10.0	7.85	2654	5.8		2192	805	283.2	23.6	320	10		12.6	43.9	1140	.048	
Middle	10/20/76	7.8	8.35	2952	3.3		2364	837	241.6	56.6	360	10		12.0	25.0	1315	.107	3.67
Upper	10/29/76	7.3	8.65	1120	2.0		730	406	144.8	10.7	100	7		7.3	2.0	228	.274	.11
Spring	10/29/76	10.0	7.90	2709	1.5		2040	760	255.2	29.7	400	10		12.1	13.8	1145	.045	
Middle	10/29/76	1.4	8.55	3065	0.78		2282	859	221.1	74.4	380	10		11.6	8.2	1335	.130	3.69

Table C-2. Continued.

Observation Location	Date Sample Taken	Field Temp°C	Field pH	Conductivity at 25°C umhos/cm	TSS mg/l	Total Alkalinity mg/l as $CaCO_3$	TDS mg/l	Total Hardness mg/l as $CaCO_3$	Ca++ mg/L	Mg++ mg/l	Na+ mg/l	K+ mg/l	Li+ mg/l	SiO_2 mg/l	Cl- mg/l	$SO_4{}^2$ mg/l	Flow (cfs)	Staff Gage (feet)
Upper	11/5/76	11.6	8.7	984	2.0		644	495	54.0	87.5	120	6		7.1	9.5	206	.039	.09
Spring	11/5/76	11.7	8.05	2746	4.3		2106	830	193.6	84.1	380	9		11.6	10.7	1190	.043	
Middle	11/5/76	8.4	8.60	3014	0.72		2322	860	304	24.3	440	8		11.1	16.7	1360	.141	3.69
Upper	11/12/76	1.6	8.80	995	2.6		620	418	134.8	19.7	110	5		6.4	4.6	190	.154	.10
Spring	11/12/76	8.8	8.20	2959	4.9		2094	903	220.4	85.6	380	9		9.8	8.2	1190	.036	
Middle	11/12/76	1.6	8.70	3133	1.8		2310	918	346.8	12.4	440	9		9.5	35.5	1365	.098	3.68
Upper	11/18/76	5.5		695	2.5		656	372	171.6		110	5		6.8	16.0	186	.038	.055
Spring	11/18/76	9.5		2848	2.5		2274	852	334.8	3.6	400	9		11.0	6.2	1315	.041	
Middle	11/18/76	2.3		2785	3.5		2288	878	257.2	57.1	400	8		10.3	16.0	1215	.118	3.69
Upper	11/24/76	0.0	8.55	1068	4.7		752	486	132.0	37.9	140	6		6.3	17.6	224	.138	.14
Spring	11/24/76	8.6	8.20	2732	2.3		2312	1127	195.6	155.1	550	9		4.8	10.9	1190	.041	
Middle	11/24/76	0.0	8.45	3104	3.0		2606	1077	846.8	111.8	470	9		9.8	18.2	1435	.097	3.69
Spring	12/2/76	6.9	8.15	2922	4.0		2158	818	166.0	98.0	360	11		9.2	16.3	1260	.036	
Middle	12/2/76	0.0	8.45	2855	0.5		2424	832			460	11		8.8	5.2	1225	Frozen	
Spring	12/15/76	7.6	8.15	2846	3.0		2308	805	244.0	47.4	420	11		11.2	2.5	1225	.036	

Table C-3. Soil sample 1:1 saturation results.

SITE	TEST HOLE	DEPTH (CM)	$CO_3^{=}$	pH	HCO_3^{-}	Cl^{-}	QUALITY meq./l $SO_4^{=}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	mmhos/@25°C CONDUCTIVITY
1 COAL CREEK 2-21-76	RIGHT BANK	0-10			.81	8.69	275.0	14.47	112.83	151.83	2.17	8.79
		10-20			.87	3.22	86.4	14.82	41.54	34.49	1.23	4.70
		20-30			.81	1.24	71.4	15.47	31.9	26.14	1.24	4.33
	LEFT BANK	0-10			.81	1.82	66.8	14.87	20.74	34.97	.63	3.54
		10-20			.52	2.18	71.9	15.02	21.96	38.23	.70	3.91
		20-30			.91	2.26	70.7	14.92	26.23	39.28	.62	3.82
2 COAL CREEK 5-1-76	RIGHT BANK	0-10	.01	8.26	.76	.13	47.8	18.21	31.0	0.90	.04	3.19
		10-20	.00	7.72	.23	.10	47.6	17.96	17.9	9.18	.02	2.87
		20-30	.00	7.74	.24	.12	49.5	17.42	29.0	0.16	.03	3.16
	CHANNEL	0-10	.01	8.26	.79	.20	12.0	5.73	1.81	3.88	.02	.551
		10-20	.00	8.17	.64	.17	10.40	5.14	1.56	1.79	.02	.437
		20-30	.01	8.32	.91	.29	12.54	7.16	3.19	2.26	.01	.694
	LEFT BANK	0-10	.00	8.07	.51	.05	20.11	17.41	1.86	0.51	.02	.467
		10-20	.00	8.06	.50	.15	9.83	8.27	0.93	0.52	.01	.316
		20-30	.00	8.14	.60	.03	9.86	8.15	1.40	0.28	.01	.297
3 COAL CREEK	RIGHT BANK	0-10	.004		0.59	0.20	89.20	24.90	21.30	14.01	0.58	5.29
		10-20	.004		0.60	0.27	71.30	26.60	22.40	22.17	0.65	4.77
		20-30	.045		2.04	5.43	81.20	19.61	25.00	39.60	0.45	5.12
	CHANNEL	0-10	.047		2.09	4.01	57.10	20.10	13.30	27.50	0.66	6.88
		10-20	.032		1.74	4.61	64.80	22.90	25.70	23.22	0.44	9.34
		20-30	.003		0.50	5.56	114.00	19.00	26.60	76.10	0.61	9.27
	LEFT BANK	0-10	.002		0.48	9.50	83.80	20.90	21.40	53.50	0.92	6.65
		10-20	.006		0.74	0.56	18.90	10.83	5.25	4.05	0.41	1.85
		20-30	.005		0.68	0.42	18.10	9.08	4.08	4.54	0.38	1.44
4 COAL CREEK 5-1-76	RIGHT BANK	0-10	.00	7.74	.13	.91	46.50	15.99	9.71	22.60	.07	4.18
		10-20	.00	7.62	.18	.86	30.60	14.20	3.71	14.40	.04	3.79
		20-30	.00	7.79	.27	1.26	45.50	14.44	5.06	25.80	.05	5.07
		30-40	.00	7.88	.33	1.43	51.93	14.38	6.99	32.20	.05	6.77
	CHANNEL	0-10	.00	8.18	.66	1.09	34.50	5.56	15.1	14.20	.02	2.23
		10-20	.01	8.21	.71	.91	11.03	7.72	3.36	2.30	.03	.620
		20-30	.01	8.33	.93	.33	12.34	8.64	3.26	1.48	.01	.601
		30-40	.00	8.11	.56	.21	11.90	8.52	2.39	0.95	.01	.458
	LEFT BANK	0-10	.00	7.99	.43	.65	34.80	16.11	12.30	3.20	.08	2.50
		10-20	.00	8.13	.59	.31	36.30	15.12	19.30	3.75	.03	2.84
		20-30	.00	8.04	.48	.46	23.30	8.83	12.80	2.78	.02	2.16

Table C-3. Continued.

SITE	TEST HOLE	DEPTH (CM)	$CO_3^=$	pH	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+	mmhos/@25°C CONDUCTIVITY
			QUALITY				meq./l					
	RIGHT	0-10			.84	7.32	40.6	6.64	27.45	24.01	.18	3.79
	BANK	10-20			1.53	.738	6.90	11.39	4.87	4.74	.10	.717
5	(clay)	20-30			1.75	1.02	8.34	.70	6.90	4.31	.08	.942
COAL	RIGHT	0-10			.81	2.25	70.6	15.42	28.85	23.49	.77	4.81
CREEK	BANK	10-20			.88	.254	27.3	6.34	17.19	5.39	.38	1.76
	(gravel)	20-30			1.75	.455	2.40	.53	7.26	3.38	.16	.625
		0-10			1.92	.301	2.90	.73	2.06	2.61	.17	.388
	CHANNEL	10-20			1.53	.099	1.09	.28	1.62	1.49	.11	.265
		20-30			1.92	4.18	0.20	.33	3.82	1.77	.10	.295
	LEFT	0-10			1.04	4.46	53.8	18.01	25.33	16.70	1.61	3.51
2-21-76	BANK	10-20			1.47	3.11	152.6	18.01	61.59	95.26	1.56	8.95
		20-30			2.01	12.6	204.9	17.81	124.6	81.64	2.33	9.50
		0-10	.00	7.66	.20	3.42	48.2	30.49	17.1	5.05	.11	2.60
	RIGHT	10-20	.01	8.24	.76	.86	11.0	5.93	3.31	4.26	.07	1.07
6	BANK	20-30	.00	8.19	.68	.97	26.3	15.40	7.69	5.18	.07	1.67
		30-40	.00	8.09	.54	1.10	35.6	22.53	11.7	2.44	.03	2.13
COAL		0-10	.01	8.2	.69	.24	12.94	7.78	3.67	1.89	.01	.634
CREEK	CHANNEL	10-20	.00	8.17	.64	.20	9.54	5.99	2.52	.80	.01	.421
		20-30	.01	8.25	.78	.16	9.46	5.68	2.37	0.98	.01	.405
	LEFT	0-10	.00	8.13	.59	.05	7.9	4.88	.42	3.15	.01	.181
5-1-76	BANK	10-20	.00	8.10	.55	.03	6.4	6.17	1.08	0.21	.01	.245
		20-30	.00	8.16	.63	.00	7.57	6.98	1.40	0.17	.01	.229
		0-10	.00	7.79	.27	6.16	138.0	12.72	93.0	41.3	.06	9.22
	RIGHT	10-20	.01	7.90	.35	4.10	71.20	8.33	49.3	17.8	.03	5.25
7	BANK	20-30	.00	7.78	.21	4.24	70.90	10.99	55.0	15.8	.04	5.87
		30-40	.00	7.82	.29	3.84	81.70	11.60	59.0	13.10	.02	5.86
COAL		0-10	.01	8.22	.72	.31	27.90	4.44	11.9	12.97	.02	1.21
CREEK	CHANNEL	10-20	.01	8.24	.76	.21	21.68	15.43	5.16	1.87	.02	.484
		20-30	.01	8.23	.74	.13	10.60	7.16	2.67	1.11	.02	.476
	LEFT	0-10	.00	8.02	.46	.09	5.98	5.31	0.51	0.17	.01	.207
	BANK	10-20	.01	8.35	.98	.03	8.87	7.35	1.76	0.17	.02	.302
5-1-76		20-30	.00	8.14	.60	.08	6.23	5.56	1.25	0.27	.01	.260

Table C-3. Continued.

SITE	TEST HOLE	DEPTH (CM)	$CO_3^=$	pH	HCO_3^-	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Na^+	K^+	CONDUCTIVITY
			QUALITY meq./l									mmhos/@25°C
8 COAL CREEK	RIGHT BANK	0-10	.006		0.76	0.18	37.4	29.4	5.39	2.55	0.43	2.85
		10-20	.005		0.71	0.28	38.1	25.9	6.57	6.51	0.41	3.62
		20-30	.009		0.93	0.83	62.8	23.5	17.4	24.6	0.78	6.08
	CHANNEL	0-10	.012		1.05	0.34	50.0	22.9	5.18	21.8	0.63	4.18
		10-20	.002		0.48	0.22	52.3	25.0	10.3	18.5	0.53	4.09
		20-30	.004		0.65	0.25	55.2	28.6	11.3	17.6	0.44	5.94
	LEFT BANK	0-10	.005		0.69	0.23	17.2	17.3	0.45	0.80	0.46	2.50
		10-20	.006		0.72	0.06	35.8	33.5	0.91	2.46	0.38	2.29
		20-30	.004		0.63	0.15	32.3	31.3	1.20	0.45	0.28	2.16
9 COAL CREEK 5-1-76	RIGHT BANK	0-10	.01	8.25	.78	.11	22.94	15.12	0.25	8.70	.08	.715
		10-20	.00	7.96	.40	.17	26.63	18.21	2.77	1.10	.08	.738
		20-30	.00	7.96	.40	.41	19.78	15.31	11.40	4.45	.12	1.54
		*	.00	7.95	.39	.38	17.91	14.51	2.81	2.26	.02	.757
	CHANNEL	0-10	.00	7.93	.37	.86	53.40	10.68	34.50	8.18	.03	4.07
		10-20	.00	8.03	.47	.33	16.90	9.07	3.83	4.25	.03	1.17
		20-30	.00	8.00	.44	.39	38.80	24.01	10.30	6.66	.03	1.56
		30-40	.00	8.03	.47	.34	40.10	26.11	10.80	4.09	.03	1.60
	LEFT BANK	0-10	.01	8.24	.76	.33	12.91	11.54	4.39	.23	.03	.540
		10-20	.00	7.94	.38	.23	27.40	10.68	21.10	0.30	.04	2.01
		20-30	.00	7.91	.35	.62	50.90	13.33	36.90	0.45	.03	2.92
10 COAL CREEK	RIGHT BANK	0-10	.002		0.48	0.47	35.9	27.7	7.50	3.12	0.47	3.28
		10-20	.004		0.58	0.17	44.6	24.4	15.7	5.56	0.43	3.05
		20-30	.003		0.51	0.24	42.8	25.0	15.3	3.08	0.46	1.20
	CHANNEL	0-10	.045		2.04	0.51	5.73	1.94	1.73	3.52	0.20	0.93
		10-20	.021		1.41	0.31	3.68	1.13	1.23	2.54	0.13	1.12
		20-30	.035		1.82	0.11	5.80	1.68	1.69	5.20	0.23	0.78
	LEFT BANK	0-10	.037		1.86	0.13	2.06	0.70	0.48	2.04	0.18	0.54
		10-20	.027		1.58	0.17	5.10	0.59	0.50	5.02	0.64	0.86
		20-30	.047		2.09	0.19	2.94	0.54	0.54	4.22	0.14	0.86

* INITIAL TEST HOLE ABORTED

Table C-3. Continued.

SITE	TEST HOLE	DEPTH (CM)	QUALITY $CO_3^{=}$	pH	HCO_3^{-}	Cl^{-}	meq. /1 $SO_4^{=}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	mmhos/@25°C CONDUCTIVITY
11 WEST TRIBUTARY 2-21-76	RIGHT BANK	0-10			1.07	.475	32.7	19.21	9.77	.82	.68	1.98
		10-20			1.03	.408	34.6	20.69	12.92	.66	.84	2.02
		20-30			---	.455	31.9	19.11	9.11	1.07	.74	2.28
	CHANNEL	0-10			1.01	.341	21.9	8.63	10.29	4.74	.32	1.31
		10-20			1.23	.498	35.5	15.57	10.5	7.57	.35	1.65
		20-30			.91	.337	38.9	18.41	12.07	5.26	.30	1.88
	LEFT BANK	0-10			.40	1.14	.376	7.93	2.54	5.08	1.11	.922
		10-20			1.07	.337	33.4	18.46	13.06	.94	.43	1.66
		20-30			.91	.652	37.9	18.41	15.13	2.45	.35	2.19
12 WEST TRIBUTARY	RIGHT BANK	0-10	.107		3.16	8.39	119.0	20.81	7.28	100.3	0.65	17.4
		10-20	.039		1.90	4.35	106.0	22.8	18.5	74.9	0.50	8.9
		20-30	.019		1.32	5.30	130.0	19.86	8.24	107.0	0.48	11.66
		30-40	.018		1.29	2.93	79.0	15.82	6.32	50.2	0.40	9.01
	CHANNEL	0-10	.013		1.12	0.11	28.2	25.95	3.93	1.48	0.47	1.81
		10-20	.009		.93	0.08	21.8	19.51	2.74	0.94	0.45	1.38
		20-30	.007		.81	0.15	21.7	17.57	2.31	2.06	0.37	2.46
	LEFT BANK	0-10	.007		0.79	0.20	22.1	22.90	0.71	0.22	0.45	2.35
		10-20	.005		0.68	0.16	23.4	24.1	0.52	0.29	0.46	2.23
		20-30	.005		0.69	0.16	33.8	31.4	1.90	1.2	0.49	2.32
13 WEST TRIBUTARY	RIGHT BANK	0-10	.054		2.24	3.90	151.00	21.36	42.20	87.80	0.67	18.9
		10-20	.014		1.15	0.91	81.20	22.01	13.20	44.50	0.47	6.41
		20-30	.004		0.59	1.13	92.70	18.06	14.60	57.20	0.47	11.48
	CHANNEL	0-10	.022		1.44	3.95	134.00	25.65	35.20	77.30	0.81	23.5
		10-20	.007		0.81	2.11	92.00	13.37	13.50	67.68	0.57	14.66
		20-30	.001		0.32	1.62	96.40	19.31	17.30	64.58	0.60	13.70
	LEFT BANK	0-10	.014		1.15	0.92	46.10	26.05	9.13	10.11	0.75	4.82
		10-20	.007		0.83	0.85	46.90	26.95	10.00	15.30	0.89	4.67
		20-30	.001		0.36	0.92	64.40	26.35	11.60	27.35	6.10	5.39
14 WEST TRIBUTARY	RIGHT BANK	0-10	.005		0.69	0.50	46.8	24.90	6.19	16.4	0.55	6.98
		10-20	.006		0.74	0.64	61.6	19.3	12.6	34.5	0.40	6.75
		20-30	.011		1.00	0.92	84.2	22.8	21.7	44.2	0.52	6.48
	CHANNEL	0-10	.007		0.83	0.60	49.9	13.8	6.27	32.7	0.55	6.03
		10-20	.006		0.72	0.68	63.0	24.0	6.71	32.3	0.46	6.55
		20-30	.011		0.76	0.41	70.5	25.7	13.8	32.0	0.48	6.48
	LEFT BANK	0-10	.045		2.04	2.25	110.	17.7	20.7	72.4	0.89	4.52
		10-20	.029		1.66	1.95	98.9	19.0	23.5	61.0	0.68	7.67
		20-30	.003		0.55	1.28	83.6	20.1	11.8	52.1	0.63	8.24

Table C-3. Continued.

SITE	TEST HOLE	DEPTH (CM)	QUALITY $CO_3^{=}$	pH	HCO_3^{-}	Cl^{-}	meq./l $SO_4^{=}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	mmhos/@25°C CONDUCTIVITY
15 WEST TRIBUTARY	RIGHT BANK	0–10	.043		1.99	0.11	2.21	1.6	1.37	1.5	1.11	1.13
		10–20	.117		3.31	0.16	0.59	.53	1.11	.52	1.17	0.44
		20–30	.170		3.98	0.56	3.76	.75	1.79	5.41	1.24	0.47
	CHANNEL	0–10	.002		0.40	1.77	87.5	23.35	37.7	28.4	0.74	13.19
		10–20	.002		0.41	0.44	45.3	25.85	14.6	6.41	0.57	3.77
		20–30	.001		0.32	0.39	46.3	21.86	13.6	13.2	0.49	4.29
	LEFT BANK	0–10	.041		1.95	1.14	79.3	18.96	40.9	22.6	1.42	5.68
		10–20	.071		2.57	0.88	38.8	4.00	20.0	15.79	0.81	3.93
		20–30	.019		1.32	0.83	66.1	19.56	30.7	16.71	1.06	6.40
16 WEST TRIBUTARY	RIGHT BANK	0–10	.003		0.55	0.19	53.7	28.99	16.0	6.84	0.56	3.75
		10–20	.004		0.60	0.20	52.3	27.01	15.5	10.26	0.47	4.55
		20–30	.001		0.24	0.40	63.0	22.41	17.3	12.86	0.55	4.28
	CHANNEL	0–10	.004		0.60	0.14	30.9	24.75	6.00	1.89	0.52	2.70
		10–20	.004		0.65	0.09	36.7	26.70	9.37	4.12	0.55	3.16
		20–30	.006		0.78	0.24	25.0	13.82	6.01	4.32	0.38	3.05
		30–40	.001		0.31	0.17	29.4	21.36	6.20	2.74	0.56	3.26
	LEFT BANK	0–10	.006		0.76	0.11	32.2	20.36	6.98	5.91	0.51	3.44
		10–20	.006		0.72	0.26	46.0	26.35	13.15	7.52	0.48	3.96
		20–30	.006		0.76	0.13	27.1	13.67	6.24	7.91	0.54	4.08
17 EAST TRIBUTARY	RIGHT BANK	0–10	.057		1.86	0.07	0.47	1.11	0.31	0.33	0.26	0.32
		10–20	.013		1.10	0.06	1.31	1.3	0.50	1.1	0.26	3.91
		20–30	.016		1.23	0.07	1.49	2.17	0.43	0.19	0.33	0.31
	CHANNEL	0–10	.007		0.83	0.35	24.30	12.87	4.98	6.26	0.50	2.77
		10–20	.007		0.79	0.37	20.50	10.03	4.49	5.18	0.40	2.18
		20–30	.006		0.76	0.36	18.20	8.88	3.64	6.58	0.32	1.77
	LEFT BANK	0–10	.022		1.44	0.09	1.02	1.42	0.65	0.22	0.21	3.52
		10–20	.004		0.59	0.08	2.41	1.10	0.64	1.50	0.17	0.56
		20–30	.031		1.70	0.07	0.29	1.54	1.03	0.42	0.10	0.32
		30–40	.054		2.24	0.19	1.47	1.32	1.16	1.39	0.34	0.30

Table C-3. Continued.

SITE	TEST HOLE	DEPTH (CM)	$CO_3^{=}$	pH	HCO_3^{-}	Cl^{-}	QUALITY meq./l $SO_4^{=}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	mmhos/@25°C CONDUCTIVITY
18 EAST TRIBUTARY	RIGHT BANK	0-10	.005		0.68	0.20	36.5	28.29	5.81	1.89	0.40	2.65
		10-20	.004		0.63	0.39	34.8	4.3	6.50	24.0	0.93	2.89
		20-30	.004		0.58	0.14	32.1	23.6	6.27	2.73	0.19	3.23
	CHANNEL	0-10	.021		1.41	2.92	91.1	20.31	40.2	47.7	0.88	15.22
		10-20	.015		1.20	1.22	43.3	13.67	23.2	18.7	0.46	5.63
		20-30	.009		0.93	1.45	62.8	19.21	30.5	15.24	0.53	5.94
		30-40	.003		0.50	1.31	70.4	24.35	26.6	21.8	0.57	5.85
	LEFT BANK	0-10	.034		1.78	4.17	98.3	22.31	42.8	37.96	0.58	10.20
		10-20	.015		1.20	1.52	76.4	21.9	28.8	30.4	0.61	5.61
		20-30	.007		0.79	1.81	48.3	13.32	13.65	24.22	0.50	5.50
		30-40	.003		0.55	1.78	37.2	11.62	11.22	16.06	0.57	5.77
19 IRRIGATION DRAINAGE STREAM	RIGHT BANK	0-10	.000		0.19	6.06	108.00	22.10	29.90	61.6	1.23	12.00
		10-20	.001		0.35	5.80	93.60	20.86	30.20	47.97	0.62	11.30
		20-30	.003		0.51	5.04	84.30	23.00	30.30	35.42	0.54	16.54
	CHANNEL	0-10	.009		0.89	4.72	117.00	20.16	45.70	67.90	0.93	40.04
		10-20	.006		0.74	9.98	162.00	20.71	55.70	94.30	0.87	45.15
		20-30	.001		0.37	4.71	111.00	25.55	40.90	50.40	0.76	10.81
		30-40	.004		0.60	3.92	97.20	18.06	23.10	59.20	0.64	11.61
	LEFT BANK	0-10	.081		2.75	5.91	92.70	23.50	29.50	48.20	1.32	17.50
		10-20	.031		1.70	6.75	114.00	14.02	31.90	77.40	1.31	14.45
		20-30	.009		0.91	4.46	98.20	27.75	34.90	41.90	0.75	6.20
20 EAST TRIBUTARY	RIGHT BANK	0-10	.00	7.87	.32	.17	38.70	21.11	15.50	4.24	.05	2.90
		10-20	.00	7.57	.16	1.36	75.90	14.75	26.20	37.00	.09	5.65
		20-30	.00	7.54	.15	2.24	77.10	13.21	25.20	44.00	.03	6.00
	CHANNEL	0-10	.00	8.01	.45	9.39	21.70	6.98	12.50	2.34	.02	1.62
		10-20	.01	8.25	.78	.08	6.68	3.40	2.20	3.92	.03	.822
		20-30	.00	8.18	.66	.47	34.40	8.09	3.98	24.30	.03	1.71
	LEFT BANK	0-10	.00	7.71	.22	.65	19.60	12.47	4.26	0.74	.06	1.70
		10-20	.00	7.94	.38	.14	34.40	17.17	11.60	1.67	.05	2.68
		20-30	.00	7.82	.29	1.50	43.20	16.11	16.50	13.30	.05	4.05

Table C-4. Coal Creek weather data.

									COAL CREEK FIELD STUDY	
								Recording Rain Gage		
Sample Site	Date	Time (MST)	Air Temp.	Wet Bulb	Relative Humidity	(in.) Rain Gage	Anemometer in miles & time	Date	Precipitation	Duration
Lower	4/8/76	1615	$63^{\circ}F$	$46^{\circ}F$	26%	0 estimated				
Lower	4/9/76	1145	$56^{\circ}F$	$40^{\circ}F$	22%	0				
Lower	4/21/76	0920	$62^{\circ}F$	$48^{\circ}F$	37%	1.05				
Spring	4/22/76	1430								
Middle	4/22/76	1130	$62^{\circ}F$	$47.5^{\circ}F$	35%	0				
Upper	4/23/76	1700	$56^{\circ}F$	$40^{\circ}F$	22%	Rain Gage Installed				
Middle	4/29/76	1055	$62^{\circ}F$	$45.5^{\circ}F$	27%	Not installed yet				
Upper	4/29/76	1215	$63^{\circ}F$	$45^{\circ}F$	23%	.05				
Lower	4/29/76	0930	$64^{\circ}F$	$46^{\circ}F$	24%	.03				
Lower	4/30/76	1435	$69^{\circ}F$	$48^{\circ}F$	20%	---				
Upper	4/30/76	1705	$64.5^{\circ}F$	$44.5^{\circ}F$	17.5%	---				
Middle	4/30/76	1545	$66^{\circ}F$	$46^{\circ}F$	21%				installed 4/30/76	
Middle	5/1/76	1445								
Spring	5/1/76	1520								
Lower	5/1/76	0900								
Upper	5/1/76	1700								
Upper	5/6/76	1930						5/6/76	.11	Light
								5/7/76	.07	Light
Middle	5/7/76	1145				.18				
Upper	5/7/76	1330				.28				
Lower	5/7/76	1430				.11				
Rain Gage West	5/7/76	1235				.17		5/8 to 5/14	.05	Light
Lower	5/13/76	1000	$78.5^{\circ}F$	$55^{\circ}F$	22%	.07				
Lower	5/14/76	1328	$86^{\circ}F$	$60^{\circ}F$	22%					
Upper	5/14/76	1452	$85^{\circ}F$	$58^{\circ}F$	20.5%	.07				
Middle	5/14/76	1658	$81^{\circ}F$	$56^{\circ}F$	20.5%					
Upper	5/20/76	0845				0 Cloudy		5/20	.35	2 hours
Lower	5/20/76	1000	$67.3^{\circ}F$			0				
Rain Gage West	5/20/76	1500	$72.8^{\circ}F$			.02				
Middle	5/20/76	1555	$69^{\circ}F$			0		5/21	.35	2 1/2 hours
Middle	5/21/76	0947	$55.9^{\circ}F$			.02				

Table C-4. Continued.

Sample Site	Date	Time (MST)	Air Temp.	Wet Bulb	Humidity	(in.) Rain Gage	Anemometer in miles & time	Recording Rain Gage Date	Recording Rain Gage Precipitation	Recording Rain Gage Duration
Upper	5/21/76	0800				.78"				
Rain Gage East	5/22/76	0920	59.5°F			.23"		5/22	.15	1/2 hour
Lower	5/22/76	1045	67.8°F			.23"				
Lower	5/23/76	0815	54.2°F			.19"				
Upper	5/24/76	0800	61°F			1.19"				
Upper	5/27/76	1800	73°F			.03				
Middle	5/27/76	1750	77°F	53°F	16%	.86"				
Rain Gage East	5/27/76	1050				.17"	Recorder = 0			
Rain Gage West	5/27/76	1650	79°F	53°F	16%	.61"				
Lower	5.28/76	0950	76°F	55°F	26%	0				
Rain Gage East	6/3/76	0900				.19"				
Rain Gage West	6/3/76	1900	73°F	49°F	15%	0				
Lower	6/3/76	1753	78°F	51°F	13%	0				
Upper	6/4/76	1100	80°F	54°F	17%	0				
Rain Gage East	6/4/76	0810	68°F	49°F	25%	0				
Middle	6/4/76	0920	76°F	52°F	18%	0				
Lower	6/10/76	1420			40%	0				
Middle	6/11/76	0815	56°F			0				
Upper	6/11/76	1035	58°F		25%	0				
Lower	6/18/76	0930	68°F	51°F	32%					
Rain Gage West	6/18/76	1053				.01				
Rain Gage East	6/18/76	1130				.02				
Ht water seepage below Middle Site	6/18/76	1232								
Middle	6/18/76	1240	77°F	55°F	25%					
Spring	6/18/76	1345								
Lower	6/21/76	1530	89°F			0				
Upper	6/21/76	1700				0				
Middle	6/22/76	0800						6/22	.10	1/4 hour
Middle	6/22/76	0845				0				
Upper	6/22/76	1245								
Lower	6/29/76	0710				.04"				
Upper	6/29/76	0800				.11"				
Spring	6/29/76	1015								
Rain Gage West	6/30/76	1045	85°F			.07"	on 7/8/76 at 1600 MST wind 7400.3			
Upper	7/1/76	1605	97.2°F	59.5°F		.02"				

Table C-4. Continued.

Sample Site	Date	Time (MST)	Air Temp.	Wet Bulb	Humidity	Rain Gage (in.)	Anemometer Reading (mi.)	Average Wind Speed During Time Interval (mi/hr)	Recording Rain Gage Date	Recording Rain Gage Precipitation	Recording Rain Gage Duration
Upper	7/9/76	0730		59.7°F	24.7%	.08"	7442.7	7442.7			
Middle	7/9/76	0845	84.7°F								
Spring	8/9/76	0955									
West Rain Gage	7/9/76	1200				.01"		3.38 mi/hr			
Upper	7/12/76	2000	21.2°C			---					
Upper	7/13/76	1210	26.8°C			.07"					
West Rain Gage	7/13/76	1800				0					
Middle	7/13/76	1727	93°F	61°F	15.5%		7801.1				
Lower	7/13/76	1915				0					
East Rain Gage	7/13/76	1830				.03					
Lower	7/14/76	0930				0		3.67 mi/hr	7/14	Trace	
Upper	7/14/76	0820									
Upper	7/14/76	1430				.20"					
Middle	7/14/76	1240					7871.5	1.98 mi/hr			
Middle	7/15/76	1630					7926.5				
Upper	7/15/76	1410				0					
Spring	7/15/76	1550							7/19	.15	1/2 Hour
Lower	7/20/76	1940				.25"			7/20	.15	1/2 Hour
Upper	7/21/76	0922				.43"		2.76 mi/hr			
East Rain Gage	7/21/76	1015				.23"					
West Rain Gage	7/21/76	1330				.28"					
Upper	7/22/76	0830				0					
Spring	7/22/76	0940									
Middle	7/22/76	1200	94°F	61.2°F	14.4%		8433.6				
Lower	7/22/76	1330				0		3.01 mi/hr			
Lower	7/27/76	0930				0					
Middle	7/27/76	1020					8790.3				
Upper	7/27/76	1305				.03"					
Upper	7/27/76	1420									
Middle	7/29/76	0715				0			7/30	.15	1 Hour
Spring	7/29/76	0800							7/31	.35	1/4 Hour
Upper	8/4/76	1000				.70"		3.33 mi/hr	8/2	.05	1/2 Hour
East Rain Gage	8/4/76	0900				.40"					
West Rain Gage	8/4/76	0900				.20"					
Lower	8/4/76	1340				.30"					
Middle	8/4/76	1515					9447.0				
Upper	8/5/76	0830									

Table C-4. Continued.

Sample Site	Date	Time (MST)	Air Temp.	Wet Bulb	Humidity	Rain Gage (in.)	Anemometer Reading (mi.)	Average Wind Speed During Time Interval (mi/hr)	Recording Rain GAge Date	Recording Rain GAge Precipitation	Recording Rain GAge Duration
Middle	8/5/76	1455	84°F	54°F	12%		9528.8				
Lower	8/5/76	1540									
Upper	8/5/76	1335									
Spring	8/5/76										
Upper	8/10/76	1705				.05"			8/8	.37	1/2 Hour
East Rain Gage	8/11/76	0735				.38"					
West Rain Gage	8/11/76	0735				.13"		3.60 mi/hr			
Macro Spring #1	8/11/76	1030									
Marco Spring #2	8/11/76	1030									
Lower	8/11/76	1156				.88"					
Upper	8/11/76	1450									
Middle	8/11/76	1450	81°F	56°F	20.5%	.39"					
Lower	8/12/76	1100									
Middle	8/12/76	1005	75°F	54.3°F	26.6%		0116.9				
Spring	8/12/76	0920									
Upper	8/12/76	0840				0					
Macro Channel #1	8/12/76	0803						3.13 mi/hr			
Upper	8/17/76	1120				0					
Middle	8/17/76	0800					0561.1				
East Rain Gage	8/17/76	1700				0		4.50 mi/hr			
West Rain Gage	8/17/76	1300				0					
Middle	8/18/76	0755				0	0668.7				
Macro Spring #1	8/18/76	1630									
Macro	8/19/76	1000						5.56 mi/hr			
Upper	8/19/76	1353									
Lower	8/19/76	1245				0					
Middle	8/19/76	1300	85°F	56.5°F	16%		0784.9				
Spring	8/19/76	1330									
Upper	8/20/76	1130				0					
Upper	8/21/76	0900									
Upper	8/21/76	1845				0					
Upper	8/22/76	1010				0		2.51 mi/hr	8/23	.43	1 5/6 Hours
Upper	8/24/76	1850				.80"					
Lower	8/24/76	1920				.21"					
East Rain Gage	8/25/76	1550				.32"					
West Rain Gage	8/25/76	1550				.60"			8/26	.12	1/2 Hour
Lower	8/27/76	0720									

Table C-4. Continued.

Sample Site	Date	Time (MST)	Air Temp.	Wet Bulb	Humidity	Rain Gage (in.)	Anemometer Reading (mi.)	Average Wind Speed During Time Interval (mi/hr)	Recording Rain Gage Date	Recording Rain Gage Precipitation	Recording Rain Gage Duration
Spring	8/27/76	0805									
Middle	8/29/76	0830	63°F	48.0°F	34%		1376.0				
Upper	8/27/76	0910									
Upper	8/31/76	1500				.01"		5.08 mi/hr			
Middle	9/1/76	1920									
West Rain Gage	9/1/76	0815				.09"					
Middle	9/1/76	0940	74.1°F	52.1°F	22.1%		1747.5				
East Rain Gage	9/1/76	0900				.14"		3.27 mi/hr			
Lower	9/2/76	0750				.04"					
Middle	9/2/76	0855	69.7°F	48.2°F	19.2%	0	1823.6				
Spring	9/2/76	0955									
Upper	9/2/76	1200				0		1.32 mi/hr	9/6	.12	1 Hour
East Rain Gage	9/7/76	1900				.49"			9/7	.20	1 Hour
Lower	9/8/76	1655				1.09"					
Middle	9/8/76	1620	74°F	55.5°F	32%		2260.7				
Upper	9/8/76	1525				.42"					
West Rain Gage	9/8/76	0800				.36"					
Spring	9/8/76	1610									
Lower	9/10/76					.01"			9/11	.35	3 Hours
Upper	9/13/76	1900				.41"			9/13	.15	10 Hours
Lower	9/13/76	1835				.63"		2.74 mi/hr	9/14	.05	10 1/2 Hours
West Rain Gage	9/14/76	0945				.52"					
East Rain Gage	9/14/76	1030				.60"					
Upper	9/14/76	0830				.17"					
Lower	9/15/76	1825				.28"					
Upper	9/15/76	1255				.08"					
Macro	9/15/76	0930				.63"					
Spring	9/15/76	1430									
Middle	9/15/76	1615	78°F	57.3°F	29.4%	.52"	2721.1				
Lower	9/21/76	1525				Trace					
East Rain Gage	9/22/76	0800				.09"					
West Rain Gage	9/22/76	0915				.05"		3.25 mi/hr			
Upper	9/22/76	1500				.01"					
Lower	9/23/76	0920				.03"					
Middle	9/23/76	1315	68°F	52.7°F	37.4%	0	3334.6	3334.6			
Upper	9/23/76	1450				.01"					
Macro	9/23/76	1715				.01"					
Upper	9/24/76	0700				0		2.30 mi/hr			
Spring	9/24/76	0730									

Table C-4. Continued.

Sampling Site	Date	Time (MST)	Air Temp.	Wet Bulb	Humidity	Rain Gage (in.)	Anemometer Reading (mi.)	Average Wind Speed During Time Interval (mi/hr)	Recording Rain Gage Date	Recording Rain Gage Precipitation	Recording Rain Gage Duration
Middle	9/24/76	0820	63.7°F	54.5°F	58.2%	0	3378.4		9/24	.05	2 1/4 Hours
Lower	9/24/76	0920				0			9/25	.02	1 1/2 Hours
Lower	9/30/76	1800				.06"					
West Rain Gage	9/30/76	1030				.02"		2.86 mi/hr			
East Rain Gage	9/30/76	1010				.05"					
Upper	10/1/76	1200				.49"					
Middle	10/1/76	0925	65.54°F	49.4°F	32.4%	.06"	3862.2				
Lower	10/1/76	0815				0					
Coal Spring	10/1/76	1040									
Macro Rain Gage	10/1/76	1400				.44"		3.13 mi/hr			
East Rain Gage	10/6/76	1430				.44"					
Lower	10/6/76	1015				.41"					
West Rain Gage	10/6/76	1345				.43"					
Lower	10/7/76	0825				0					
Macro Rain Gage	10/8/76	0945				.56"			10.2	.47	14 Hours
Spring	10/8/76	1335									
Lower	10/8/76	1510				0					
Middle	10/8/76	1435	65.7°F	46.2°F	20.7%	.54"	4403.7				
Upper	10/8/76	0907				.73"					
East Rain Gage	10/13/76	1450				0					
West Rain Gage	10/13/76	1530				0					
Lower	10/14/76	0900				0		2.65 mi/hr			
Upper	10/15/76	1600				0					
Macro Rain Gage	10/15/76	1235				0			10/2	.47	14 Hours
Middle	10/15/76	0845	57.3°F	41.3°F	23.6%	0	4833.8				
Spring	10/15/76	1050									
Lower	10/15/76	0745									
Upper	10/20/76	1615									
Spring	10/20/76	1645									
Middle	10/20/76	1716				0					
East Rain Gage	10/20/76					0		3.03 mi/hr	10/3	.04	12 Hours
Macro Rain Gage	10/20/76					0					
West Rain Gage	10/20/76					0					
West Rain Gage	10/27/76	1630				0					
Upper	10/27/76	1700									
Lower	10/28/76	1535				0					

Table C-4. Continued.

Sampling Site	Date	Time (MST)	Air Temp.	Wet Bulb	Humidity	Rain Gage (in.)	Anemometer Reading (mi.)	Average Wind Speed During Time Interval (mi/hr)	Recording Rain Gage Date	Recording Rain Gage Precipitation	Recording Rain Gage Duration
East Rain Gage	10/28/76	1730				0					
Spring	10/29/76	0955									
Middle	10/29/76	1010	35.7°F	31.1°F	62.6%	0	5857.6				
Macro Rain Gage	10/29/76	1045				0					
Upper	10/29/76	1215									
East Rain Gage	11/3/76	1615				0		2.20 mi/hr			
Upper	11/3/76	1700				0					
West Rain Gage	11/4/76	1350				0					
Lower	11/4/76	1800				0					
Middle	11/5/76	1030	53.2°F	41.1°F	35.8%	0	6219.2				
Spring	11/5/76	1135									
Coal Creek Macro Rain Gage	11/5/76	1155				0					
Upper	11/5/76	1330				0		2.22 mi/hr			
East Rain Gage	11/11/76	0900				0					
West Rain Gage	11/11/76	0945				0					
Lower	11/11/76	1115				0					
Macro Rain Gage	11/11/76	1430				0					
Middle	11/12/76	0940	39.0°F	30.1°F	84.8%	0	6590.2				
Spring	11/12/76	1030									
Upper	11/12/76	1150				0					
Lower	11/16/76	1530				0					
Rain Gage West	11/16/76	1620				.01"					
Rain Gage East	11/16/76	1700				.01"		2.57 mi/hr			
Upper	11/17/76	1535				.04"					
Macro Rain Gage	11/17/76	1600				.04"					
Middle	11/18/76	0935	45.5°F	39.0°F	58.5%	.01"	6960.4				
Spring	11/18/76	1035									
Upper	11/18/76	1135				0					
Lower	11/22/76	1445				0			11/15	.01	
East Rain Gage	11/22/76	1500				0					
West Rain Gage	11/22/76	1400				0					
Macro Rain Gage	11/23/76	1650				0		2.28 mi/hr			
Upper	11/23/76	1620				0					
Spring	11/24/76	1035									

Table C-4. Continued.

Sampling Site	Date	Time (MST)	Air Temp.	Wet Bulb	Humidity	Rain Gage (in.)	Anemometer Reading (mi.)	Average Wind Speed During Time Interval (mi/hr)	Recording Rain Gage Date	Precipitation	Duration
Middle	11/24/76	0945	34.5°F	28.1°F	46.3%	0	7289.7				
Upper	11/24/76	1140				0					
Lower	11/30/76										
Macro Rain Gage	12/1/76	0900				.01"		3.16 mi/hr			
West Rain Gage	12/2/76	0905				Trace					
East Rain Gage	12/2/76	0955				Trace					
Upper	12/2/76	1145				.02"					
Spring	12/2/76	1510									
Middle	12/2/76	1550	41.0°F	31.5°F	35%		7827.7				
Macro Rain Gage	12/15/76	0945				0					
Upper	12/15/76	0925				0		2.18 mi/hr			
Spring	12/15/76	1155									
Middle	12/15/76	1510	50.7°F	36.2°F	21.4%		8506.5				
West Rain Gage	12/15/76	1415				0					
East Rain Gage	12/15/76	1615				0					
Lower	12/15/76	1715				0					

Table C-5. Coal Creek storm data.

Date: May 21

Duration: 2 1/2 hrs.
Began: 1230 MST

Station	Thiessen Area Sq. Miles	Precipitation Inches	Product Sq. Miles
Upper	11.23	.48	5.39
Middle	3.17	.35	1.11
East	1.36	.23	.31
West	4.42	.25	1.11
Lower	1.28	.17	.22
Totals	21.46	1.48	8.14

Average Precipitation = .38 inches

Date: May 22

Duration 1/2 hr
Began: 1300 MST

Station	Thiessen Area Sq. Miles	Precipitation Inches	Product Precip. x Area
Upper	11.23	.22	2.47
Middle	3.17	.15	.48
East	1.36	.17	.23
West	4.42	.11	.49
Lower	1.28	.07	.09
Totals	21.46	.72	3.76

Average Precipitation = .18 inches

Date: June 22

Duration: 1/4 hr
Began: 1145 MST

Station	Thiessen Area Sq. Miles	Precipitation Inches	Product Precip. x Area
Upper	11.23	.11	1.24
Middle	3.17	.10	.32
East	1.36	.04	.05
West	4.42	.03	.13
Lower	1.28	.07	.09
Totals	21.46	.35	1.83

Average Precipitation = .09 inches

Table C-5. Continued.

Date: July 19

Duration: 1/2 hr.
Began: 1330 MST

Station	Thiessen Area	Precipitation Inches	Product Precip. x Area
Upper	11.23	.22	2.47
Middle	3.17	.15	.48
East	1.36	.12	.16
West	4.42	.14	.62
Lower	1.28	.13	.17
Totals	21.46	.76	3.90

Average Precipitation = .18 inches

Date: July 20

Duration: 1/2 hr.
Began: 2350 MST

Station	Thiessen Area Sq. Miles	Precipitation Inches	Product Precip. x Area
Upper	11.23	.22	2.47
Middle	3.17	.15	.48
East	1.36	.12	.16
West	4.42	.14	.62
Lower	1.28	.13	.17
Totals	21.46	.76	3.90

Average Precipitation = .18 inches

Date: July 30

Duration: 1 hr.
Began: 2300 MST

Station	Thiessen Area Sq. Miles	Precipitation Inches	Product Precip. x Area
Upper	11.23	.19	2.13
Middle	3.17	.15	.48
East	1.36	.11	.15
West	4.42	.05	.22
Lower	1.28	.08	.10
Totals	21.46	.58	3.23

Average Precipitation = .15 inches

Table C-5. Continued.

Date: July 31 | Duration: 1/4 hr. | Began: 1640 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.45	5.05
Middle	3.17	.35	1.11
East	1.36	.25	.34
West	4.42	.13	.57
Lower	1.28	.19	.24
Totals	21.46	1.37	7.31

Average Precipitation = .34 inches

Date: August 2 | Duration: 1/2 hr. | Began: 1555 MST

Station	Thiessen Area	Precipitation Inches	Product Precip. x Area
Upper	11.23	.06	.67
Middle	3.17	.05	.16
East	1.36	.04	.05
West	4.42	.02	.09
Lower	1.28	.03	.04
Totals	21.46	.20	1.01

Average Precipitation = .05 inches

Date: August 8 | Duration: 1/2 hr. | Began: 1245 MST

Station	Thiessen Area	Precipitation Inches	Product Precip. x Area
Upper	11.23	.05	.56
Middle	3.17	.37	1.17
East	1.36	.38	.52
West	4.42	.13	.57
Lower	1.28	.88	1.13
Totals	21.46	1.81	3.95

Average Precipitation = .18 inches

Table C-5. Continued.

Date: August 22 | Duration: 1 5/6 hrs. | Began: 1835 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.80	8.98
Middle	3.17	.43	1.36
East	1.36	.32	.44
West	4.42	.60	2.65
Lower	1.28	.21	.27
Totals	21.46	2.36	13.70

Average Precipitation = .64 inches

Date: August 26 | Duration: 1/6 hr. | Began: 1440 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.01	.11
Middle	3.17	.12	.38
East	1.36	.14	.19
West	4.42	.09	.40
Lower	1.28	.04	.05
Totals	21.46	.40	1.13

Average Precipitation = .05 inches

Date: September 6 | Duration: 1 hr. | Began: 1355 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.16	1.80
Middle	3.17	.12	.38
East	1.36	.18	.24
West	4.42	.14	.62
Lower	1.28	.41	.52
Totals	21.46	1.01	3.56

Average Precipitation = .17 inches

Table C-5. Continued.

Date: September 7 — Duration: 1 hr. Began: 0500 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip x Area
Upper	11.23	.26	2.92
Middle	3.17	.20	.63
East	1.36	.31	.42
West	4.42	.23	1.02
Lower	1.28	.68	.87
Totals	21.46	1.68	5.86

Average Precipitation = .27 inches

Date: September 11 — Duration: 3 hr. Began: 1730 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.41	4.60
Middle	3.17	.35	1.11
East	1.36	.42	.57
West	4.42	.36	1.59
Lower	1.28	.63	.81
Totals	21.46	2.17	8.68

Average Precipitation = .41 inches

Date: September 13 — Duration: 10 hr. Began: 1915 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip x Area
Upper	11.23	.17	1.91
Middle	3.17	.15	.48
East	1.36	.18	.24
West	4.42	.16	.71
Lower	1.28	.21	.27
Totals	21.46	.87	3.61

Average Precipitation = .17 inches

Table C-5. Continued.

Date: September 14 Duration: 10 1/2 hr.
Began: 1930 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip x Area
Upper	11.23	.08	.90
Middle	3.17	.05	.16
East	1.36	.09	.12
West	4.42	.05	.22
Lower	1.28	.07	.09
Totals	21.46	.34	1.49

Average Precipitation = .07 inches

Date: September 24 Duration: 2 1/4 hr.
Began: 1145 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.35	3.93
Middle	3.17	.05	.16
East	1.36	.04	.05
West	4.42	.01	.04
Lower	1.28	.04	.05
Totals	21.46	.49	4.23

Average Precipitation = .20 inches

Date: September 25 Duration: 1 1/2 hr.
Began: 1300 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.14	1.57
Middle	3.17	.02	.06
East	1.36	.01	.01
West	4.42	.01	.04
Lower	1.28	.02	.03
Totals	21.46	.2[illegible]	1.71

Average Precipitation = .08 inches

Table C-5. Continued.

Date: October 2

Duration: 14 hrs
Began: 0400 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.67	7.52
Middle	3.17	.47	1.49
East	1.36	.41	.56
West	4.42	.40	1.77
Lower	1.28	.38	.49
Totals	21.46	2.33	11.83

Average Precipitation = .55 inches

Date: October 3

Duration: 12 hr.
Began: 2430 MST

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.06	.67
Middle	3.17	.04	.13
East	1.36	.03	.04
West	4.42	.03	.13
Lower	1.28	.03	.04
Totals	21.46	.19	1.01

Average Precipitation = .05 inches

Date: October 15

Duration:
Began:

Station	Thiessen Area (mi^2)	Precipitation Inches	Product Precip. x Area
Upper	11.23	.04	.45
Middle	3.17	.01	.03
East	1.36	.01	.01
West	4.42	.01	.04
Lower	1.28	0	0
Totals	21.46	.07	.53

Average Precipitation = .02 inches

Table C-6. Surface crust salt potential.

Soil Sample Site No.	Estimated gms salt/m^2-cm February 9-10, 1977	July 7-9, 1977
2	108	21
3	---	148
4	---	37
5	---	48
6	52	95
7	56	137
8	2717	5946
9	175	22
10	74	69
11	253	674
12	396	663
13	1807	1639
14	1023	1163
15	1558	3125
16	359	491
17	140	252
18	422	322
19	9387	8063
20	74	18
	$\overline{X} = 1163$ S = 2327	$\overline{X} = 1207$ S = 2209

For both dates $\overline{X} = 1187$ S = 2230

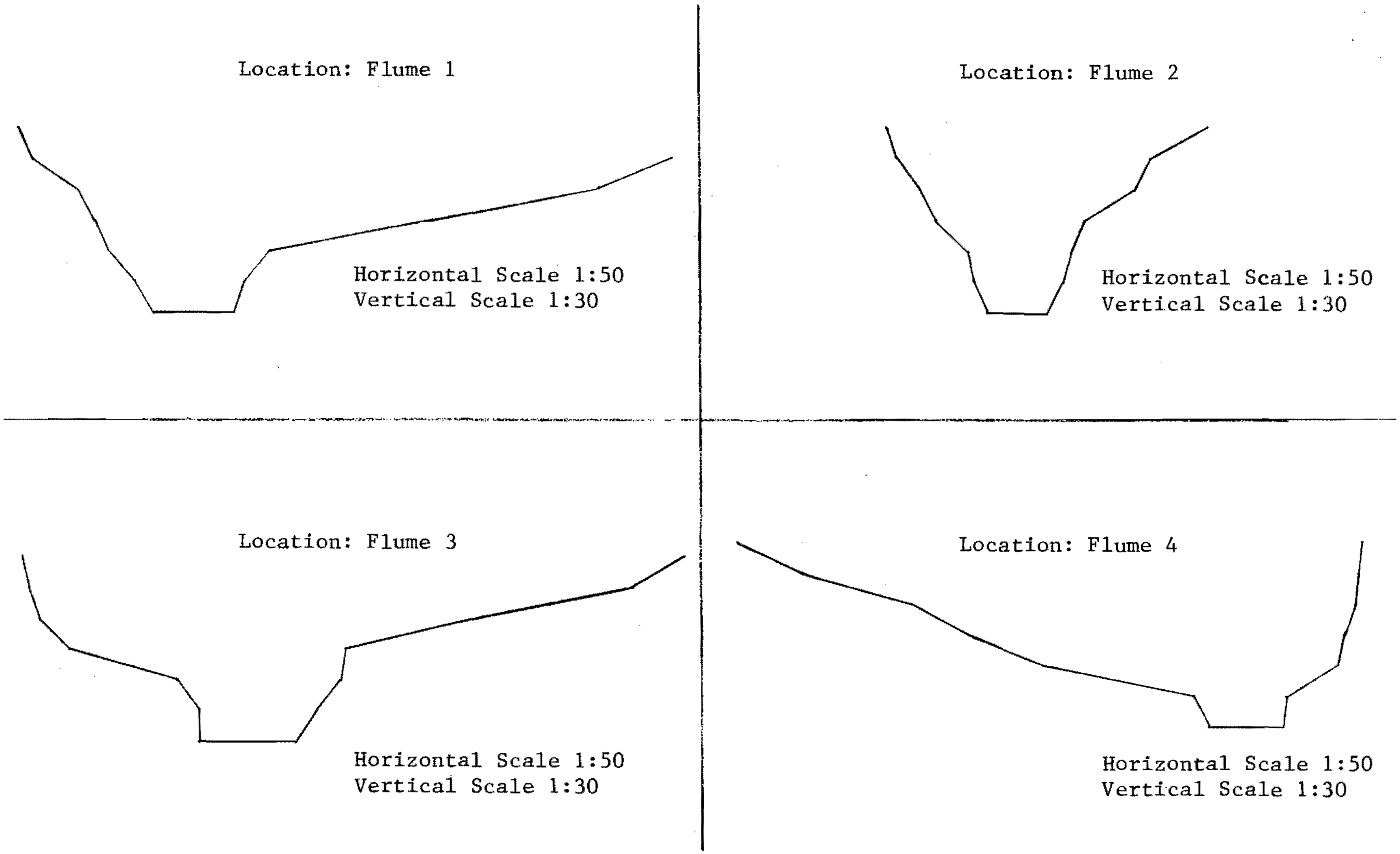

Figure C-3. Channel cross sections of the Macrochannel.

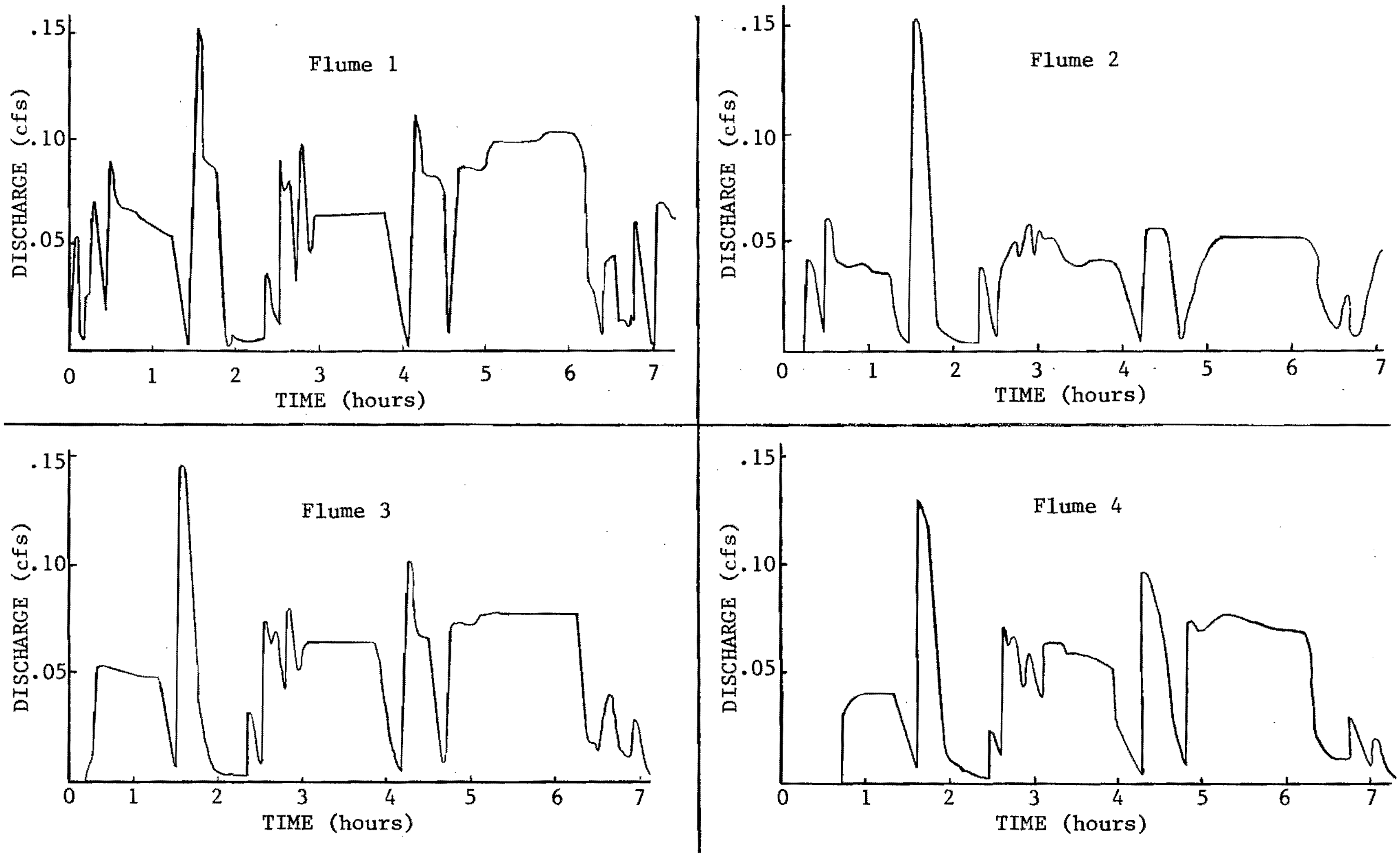

Figure C-4. Macrochannel flow hydrographs for August 26, 1976.

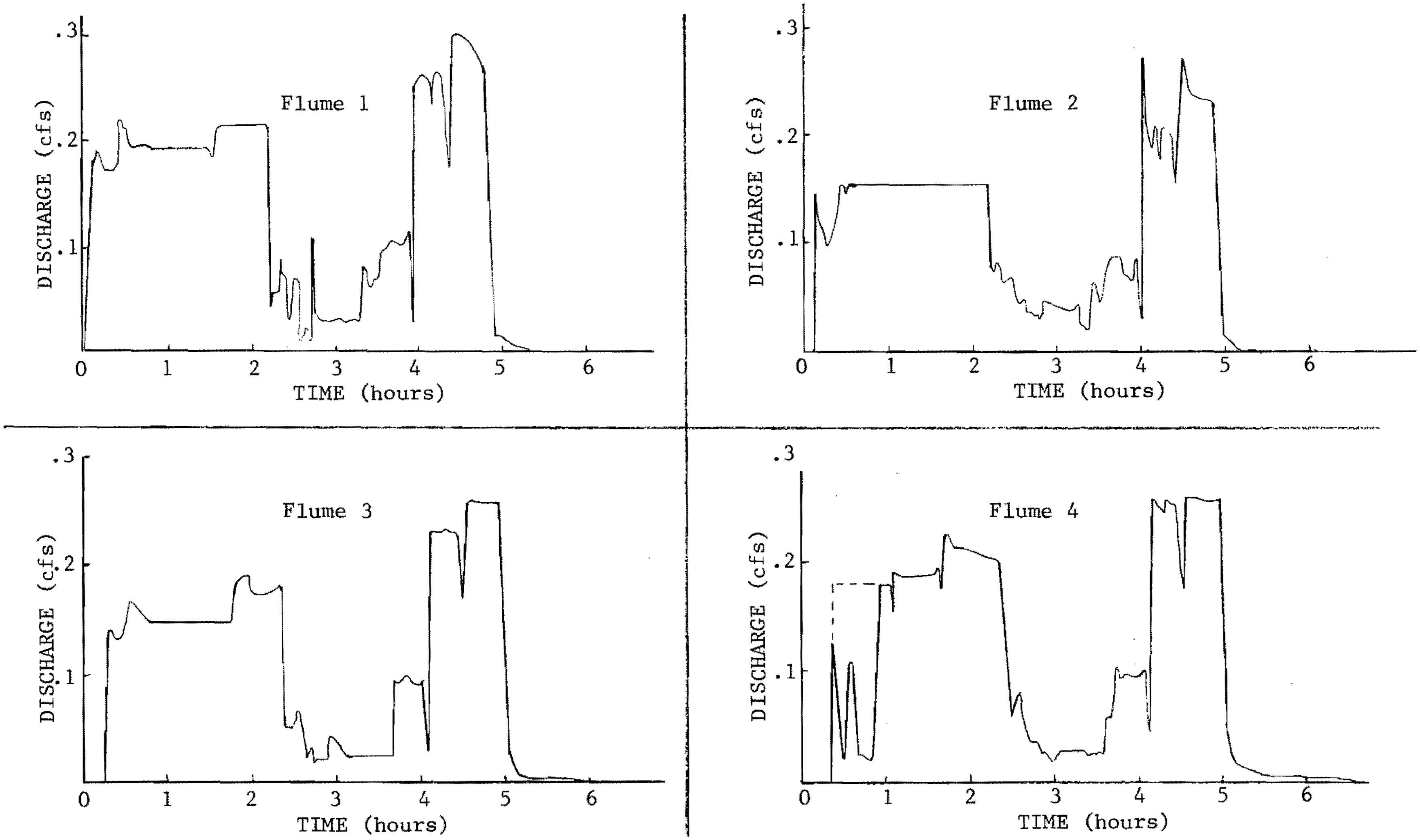

Figure C-5. Macrochannel flow hydrographs for September 9, 1976.

Table C-7. Macrochannel study of August 26, 1976.

Sample #	Flume #	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Ph	TSS[a] mg/l	TDS[b] mg/l	Total Hardness mg/l $CaCo_3$	Ca^{++} mg/l	Mg^{++} mg/l	Na^{+} mg/l	K^{+} mg/l	SiO_2 mg/l	Cl^{-} mg/l	$SO_4^{=}$ mg/l	Flow cfs
#1 810	1	0810	17.2	1308	8.15	166	872	480	121	43	90	9	7.8	19	340	.064
#1 824	1	0824	16.1	1523	8.2	424	1032	571	146	50	96	12	8.9	23	466	.057
#2 734	2	0734	16.1	3361	8.2	1278	2868	1551	620	141	230	28	9	38	1520	.003
#2 748	2	0748	19.4	1730	8.3	141	1250	776	310	66	97	14	6.9	20	665	.033
#2 835	2	0835	16.7	1510	8.35	182	1030	612	245	41	88	12	7.1	19	508	.036
#3 756	3	0756	15.6	2906	8.25	857	2542	1337	364	103	220	20	8.2	30	1600	.006
#3 827	3	0827	16.1	1714	8.35	787	1216	704	186	58	90	12	7.8	19	599	.050
#4 816	4	0816	16.7	2540	8.30	42	1924	1041	432	–	160	18	8.5	23	1110	.035
#1 840	1	0840	17.8	1318	8.40	284	912	480	133	36	88	10	8.2	18	380	.051
#1 945	1	0945	21.7	1269	8.25	132	840	459	85	60	84	9	7.9	19	364	.019
#2 945	2	0945	23.9	1483	8.15	394	1074	653	261	48	9	11	7.7	19	444	.038
#3 944	3	0944	25.0	1619	8.15	538	1196	714	208	47	92	13	8.0	19	615	.003
#4 1000	4	1000	23.9	1934	8.15	1258	1480	888	250	63	100	16	8.3	20	750	.023
#1 1100	1	1100	21.2	1257	8.00	106	826	469	117	43	84	9	7.9	18	336	.063
#2 1057	2	1057	23.8	1428	8.15	214	1052	643	170	53	84	10	6.9	18	445	.039
#3 1055	3	1055	25.0	1416	8.00	292	1002	592	174	38	86	10	7.5	18	500	.065
#4 1050	4	1050	26.1	1495	8.05	211	1014	582	174	36	90	11	8.1	18	506	.064
#1 1205	1	1205	22.5	1276	8.00	137	852	500	113	53	86	9	7.8	18	352	.068
#2 1200	2	1200	23.3	1390	8.20	132	944	510	166	23	86	10	7.7	19	446	.042
#3 1203	3	1203	24.3	1496	8.20	507	1090	582	182	31	90	10	7.3	19	546	.043
#4 1152	4	1152	26.7	1532	8.10	763	1042	592	170	41	88	10	7.7	19	600	.095
#1 1240	1	1240	22.2	1256	8.15	100	848	459	117	40	84	9	7.3	19	370	.098
#2 1245	2	1245	21.6	1314	8.15	50	868	510	154	31	83	10	7.7	19	398	.052
#3 1247	3	1247	21.2	1400	8.10	355	924	480	168	15	88	10	7.2	18	444	.079
#4 1245	4	1245	21.6	1448	8.25	1016	936	551	162	36	90	11	8.1	20	436	.078
#1 1346	1	1346	22.2	1352	8.20	65	868	490	117	48	90	10	8.1	20	366	.015
#2 1343	2	1343	24.8	1334	8.20	58	948	510	139	39	82	10	7.7	18	424	.044
#3 1345	3	1345	23.6	1386	8.25	115	918	520	154	33	84	10	7.4	19	440	.079
#4 1345	4	1345	24.2	1369	8.25	97	884	520	170	23	82	10	7.7	19	416	.067
#1 1445	1	1445	20.7	1263	8.20	88	816	449	182	43	77	9	7.8	19	340	.064
#2 1445	2	1445	20.6	1287	8.30	149	884	520	152	34	83	10	7.5	19	382	.045
#3 1444	3	1444	20.7	1471	8.25	193	1024	582	186	28	88	11	6.9	19	500	.064
#4 1448	4	1448	21,2	1551	8,39	109	1158	622	292	28	90	11	8.6	19	436	.060

[a]Total Suspended Solids
[b]Total Dissolved Solids

Table C-8. Macrochannel study of September 9, 1976.

Sample #	Flume #	Time (MST)	Temperature °C	Conductivity (umhos @25°C)	pH	TSS[a] mg/l	TDS[b] mg/l	Flow cfs
#1 0649	1	0649	16.4	1310	8.10	12,600	997	.088
#3 0702	3	0702	12.7	1967	8.10	45,404	1578	.005
#4 0655	4	0655	13.2	1384	8.30	23,508	1047	.005
#1 0710	1	0710	15.6	1272	8.25	8,136	947	.196
#2 0705	2	0705	12.8	1278	8.25	13,720	1062	.100
#3 0720	3	0720	13.1	1478	8.20	30,372	1126	.150
#1 0730	1	0730	15.6	1260	8.30	6,640	888	.195
#2 0725	2	0725	20.0	1367	8.15	13,036	997	.178
#3 0730	3	0730	13.4	1429	8.25	14,696	1210	.158
#4 0704	4	0704	22.6	1934	7.90	23,872	1617	.008
#1 0745	1	0745	20.9	1265	8.15	5,500	627	.192
#2 0745	2	0745	14.8	1314	8.25	14,856	965	.178
#3 0745	3	0745	19.7	1052	8.15	23,204	1035	.147
#1 0845	1	0845	28.4	1258	8.05	4,868	933	.214
#2 0847	2	0847	23.5	1303	8.20	10,816	950	.178
#3 0846	3	0846	24.2	1355	8.15	12,864	997	.191
#4 0852	4	0852	24.6	1355		17,016	1024	.209
#1 1004	1	1004	28.2	1258	8.15	4,652	939	.030
#2 1000	2	1000	31.1	1314	8.10	8,988	1022	.038
#3 0955	3	0955	31.8	1388	8.10	21.800	1132	.025
#4 0945	4	0945	29.7	1533	8.05			.016
#1 1046	1	1046	24.2	1284	8.10			.256
#2 1050	2	1050	26.7	1353	8.10			.271
#3 1045	3	1045	25.8	1343	8.15			.091
#4 1045	4	1045	27.1	1367	8.15			.095
#1 1137	1	1137	22.8	1296	8.20			.148
#2 1139	2	1139	23.9	1293	8.15			.234
#3 1145	3	1145	23.8	1490	8.15			.261
#4 1143	4	1143	22.8	1374	8.20			.260

[a]Total Suspended Solids
[b]Total Dissolved Solids

Table C-9. Soil sensor results.

Date	UPPER				MIDDLE				LOWER			
	5783	5779	5768	5762	5784	5777	5767	5756	5796	5751	5776	5757
8/25/76	15.2°/4100	17.3°/4400	19.6°/3010	18.3°/5150	19.8°/0775	19.4°/7950	18.2°/6020	19.0°/7350	14.2°/11700	14.8°/7450	16.6°/5900	17.8°/17175
8/31/76	24.5°/2600	19.5°/4100	19.6°/3775	18.4°/4325	23.7°/6200	23.0°/15200	21.1°/7625	20.6°/9175	32.3°/1250	23.5°/5920	19.8°/4900	18.2°/14720
9/2/76	16.8°/2600	17.8°/3950	19.8°/3600	19.0°/4200	26.1°/5500	22.2°/13120	19.4°/7550	19.5°/10575	26.8°/1425	18.4°/5650	17.5°/4220	17.8°/14550
9/7/76	17.7°/2700	19.0°/4050	20.1°/3450	18.6°/4520	16.7°/4900	18.3°/12500	19.0°/6750	19.5°/8150	16.0°/2700	19.0°/5350	19.0°/3900	18.2°/12175
9/8/76	12.8°/2520	14.2°/3950	17.5°/4320	17.5°/4600	21.1°/5420	19.4°/12100	17.8°/6290	17.8°/8000	19.5°/3375	15.5°/5625	14.8°/4600	16.6°/12050
9/9/76	10.4°/2600	14.2°/3975	17.4°/3500	17.3°/4600	12.0°/5510	14.4°/12675	16.6°/6500	17.5°/7950	8.3°/2300	12.4°/5125	14.8°/4600	16.7°/112125
9/9/76	11.3°/2700	13.8°/4025	17.2°/3430	16.8°/4600	13.8°/5120	14.4°/12500	16.4°/6450	17.5°/7725	12.0°/2800	12.4°/5125	14.5°/4700	16.3°/12120
9/9/76	16.6°/2590	15.0°/3925	16.6°/3550	16.6°/4675	20.6°/6130	20.3°/12500	13.8°/7500	18.4°/7750	25.2°/3220	16.6°/6200	16.2°/4820	15.8°/12450
9/10/76		15.9°/3625	17.5°/3475	16.8°/4600	20.7°/6575	18.6°/14100	13.8°/8250	17.8°/8150	20.7°/3620	17.4°/5600	15.8°/4820	16.3°/12600
9/15/76	12.7°/1825	14.2°/2575	16.6°/4000	16.1°/4590	21.8°/6300	18.4°/13600	16.3°/7350	16.4°/8750	22.8°/2720	15.7°/4700	14.3°/4950	15.2°/12600
9/23/76	16.6°/2200	16.3°/2900	17.3°/4000	16.3°/4620	19.6°/4000	19.3°/12920	18.2°/6875	18.1°/8300	19.8°/<500	19.8°/3800	18.3°/3420	16.7°/10825
10/1/76	14.8°/2000	13.3°/2990	15.0°/3825	14.7°/4600	20.3°/3950	18.8°/13020	16.6°/6220	16.3°/7100	25.2°/<500	18.3°/4090	15.4°/3475	14.3°/9200
10/8/76	5.0°/1800	7.8°/1625	11.2°/4000	11.7°/4325		16.6°/9220	11.5°/6175	11.7°/7850		9.4°/2450	8.0°/3620	10.2°/9300
10/15/76	8.7°/1650	9.6°/1950	12.0°/3850	12.0°/4475		16.0°/4250	14.2°/4920	13.8°/6325		14.6°/2150	11.1°/2700	11.1°/8450
10/29/76	2.8°/1100	5.4°/2425	8.4°/2975	8.8°/4425		12.8°/3120	9.7°/3820	9.6°/5200		3.4°/3250	4.3°/1625	6.6°/5625
11/5/76	4.5°/950	6.2°/2650	8.9°/3300	9.0°/4410		12.3°/2810	10.8°/2720	10.6°/5750		4.2°/825	5.2°/1400	7.2°/5100
11/17/76	4.7°/700	5.3°/2700	7.5°/2425	7.3°/4320		8.3°/2400	8.7°/3520	9.1°/5150		3.8°<500	5.6°/1120	6.1°/5100
11/23/76	3.6°/700	4.5°/2825	6.7°/2275	6.7°/4250		6.5°/2300	7.7°/3475	8.3°/5200		2.5°<500	3.7°/1150	5.2°/5090
12/1/76	0.0°<500	0.0°<500	2.3°/1860	2.8°/4050	washed out	2.9°/2300	3.2°/3340	3.8°/4230	washed out	0.0°<500	0.0°<500	1.2°/5230
12/15/76	0.0°<500	0.0°<500	2.0°/1820	2.3°/2350		2.2°/1975	1.7°/3220	2.6°/4500		0.0°<500	0.0°<500	0.8°/5070
1/25/77	0.0°/1100	.7°<500	2.3°/1950	1.8°/1700		0.0°/9825	0.0°/3830	1.0°/5500		0.0°<500	0.4°/620	1.7°/4500
2/18/77	0.4°/1675	1.3°<500	3.2°/1700	2.7°/1675		7.7°/4350	5.2°/4275	4.6°/6450		3.5°/875	1.5°/700	2.4°/3750
3/17/77	3.6°/1300	3.3°<500	4.8°/1850	3.9°/1700		6.0°/2250	4.2°/3750	4.5°/6325		4.5°/600	3.8°/800	4.2°/3750
3/24/77	5.3°<500	3.0°<500	4.5°/2450	4.1°/2800		8.9°/700	5.0°/4990	4.6°/7430		5.2°<500	4.0°/1425	4.2°/1200
5/5/77	washed out	15.0°<500	13.8°/2600	11.8°/3300		washed out	washed out	14.0°/5500		17.4°<500	14.2°<500	12.3°/1850
6/2/77		12.8°/2700	13.3°/3080	12.6°/3450				16.3°/8760		17.8°/4075	13.8°/5730	12.8°/5320

APPENDIX D

LABORATORY DATA

Table D-1. Saturation dissolution results.

SOURCE: Experimental Channel, 20' above Probes, 3/4' above channel bottom

CONTROL GROUP

Date	SAMPLE NO. 1 Initial Weight Soil = 326.7 gms Initial Volume Water = 326.7 ml			SAMPLE NO. 2 Initial Weight Soil = 298 gms Initial Volume Water = 298 ml			SAMPLE NO. 3 Initial Weight = 335 gms Initial Volume = 335 ml		
	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @25°C)
11/1/76	1358	---	INITIAL	1402	---	INITIAL	1404	---	INITIAL
11/1/76	1406	25	117	1417	25	207	1418	25	122
11/2/76	0858	21.1	874	0900	21.1	939	0901	21.1	873
11/3/76	0828	21.5	1060	0831	21.5	1189	0833	21.5	1142
11/4/76	0835	21.5	1166	0835	21.5	1342	0837	22.0	1272
11/5/76	0940	22.0	1166	0940	22.0	1356	0940	22.0	1278
11/6/76	1212	24.0	1282	1212	24.0	1592	1212	24.0	1548
11/8/76	1650	21.5	1201	1650	21.5	1391	1650	21.5	1370
11/10/76	1232	22.0	1241	1231	22.0	1485	1231	22.0	1441
11/11/76	1549	22.0	1308	1549	22.0	1507	1549	22.0	1474
11/12/76	0949	22.5	1203	0949	22.5	1409	0949	22.5	1388
11/15/76	1442	20.0	1352	1442	20.0	1573	1442	20.0	1515
11/18/76	0937	20.5	1388	0937	20.5	1562	0937	20.5	1504
11/23/76	0954	21.0	1356	0954	21.0	1571	0954	21.0	1571
11/30/76	1039	21.0	1373	1041	21.0	1620	1042	21.0	1564
12/2/76	1202	23.2	1423	1203	23.5	1676	1204	23.8	1589
12/7/76	1100	20.5	1387	1102	20.5	1594	1102	20.0	1545
12/16/76	1502	23.7	1427	1502	23.7	1654	1502	23.7	1643
12/16/76	---WATER CHANGED---								
12/20/76	1545	23.8	268	1548	23.8	264	1550	23.6	256
12/21/76	0900	24.0	304	0901	24.0	296	0902	24.0	294
12/22/76	0826	22.0	323	0827	22.0	314	0828	22.0	317
12/22/76	1327	21.8	342	1328	21.8	339	1328	21.8	336
12/28/76	0820	21.7	386	0821	21.7	387	0822	21.7	383
1/03/77	1352	22.0	442	1353	22.0	497	1354	22.0	486
1/11/77	0919	22.0	505	0920	22.0	503	0921	22.0	503
1/18/77	1041	22.0	531	1042	21.7	534	1044	21.8	533
1/27/77	0933	22.0	569	0934	22.0	574	0955	22.0	569

Table D-1. Continued.

SOURCE: Above Spring, Coal Creek

CONTROL GROUP

Date	SAMPLE NO. 4 Initial Weight = 363 gms Initial Volume = 363 ml			SAMPLE NO. 5 Initial Weight = 286.8 gms Initial Volume = 286.8 ml			SAMPLE NO. 6 Initial Weight = 284.3 gm Initial Volume = 284.3 ml		
	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)
11/1/76	1406	-------INITIAL	-------------	1409	----------INITIAL	-----------	1411	---------- INITIAL	---------
11/1/76	1419	25	57	1420	25.0	89	1421	25.0	67
11/2/76	0911	21.1	279	0912	21.1	404	0912	21.1	321
11/3/76	0836	21.5	389	0836	21.5	589	0836	21.5	489
11/4/76	0841	21.5	459	0841	21.5	683	0841	21.5	594
11/5/76	0944	22.0	505	0944	22.0	748	0944	22.0	639
11/6/76	1219	24.0	586	1219	24.0	851	1219	24.0	696
11/8/76	1654	21.5	606	1654	21.5	850	1654	21.5	776
11/10/76	1235	22.0	652	1235	22.0	931	1235	22.0	853
11/11/76	1632	22.5	713	1631	22.5	965	1631	22.5	888
11/12/76	0952	22.5	689	0952	22.5	915	0952	22.5	843
11/15/76	1446	20.5	773	1446	20.5	1015	1446	20.5	957
11/18/76	0940	20.5	810	0940	20.5	1041	0940	20.5	1006
11/23/76	1000	21.0	842	1000	21.0	1062	1000	23.0	987
11/30/76	1045	21.0	878	1045	21.0	1080	1047	21.0	1046
12/2/76	1207	23.8	897	1209	23.8	1092	1209	23.8	1075
12/7/76	1105	20.5	873	1106	20.5	1070	1107	20.2	1033
12/16/76	1516	24.2	864	1516	24.2	1086	1516	24.2	1097
12/16/76	-----	-----	-----	---WATER CHANGED	-----	-----	-----	-----	-----
12/20/76	1552	24.0	157	1555	23.8	150	1557	23.8	146
12/21/76	0908	24.0	170	0910	24.0	169	0911	24.0	161
12/22/76	0832	22.0	184	0833	22.0	181	0834	22.0	174
12/23/76	1330	21.8	199	1331	21.8	197	1332	21.8	189
12/28/76	0825	21.7	237	0826	21.7	233	0827	21.7	223
1/3/77	1356	22.0	279	1357	22.0	274	1358	22.0	264
1/1/77	0924	22.2	319	0925	22.2	312	0926	22.2	296
1/18/77	1052	22.0	337	1053	22.0	330	1054	22.0	319
1/27/77	0937	22.0	359	0928	22.0	351	0938	22.0	340

Table D-1. Continued.

SOURCE: Lower Site, Coal Creek

CONTROL GROUP

Date	SAMPLE NO. 7 Initial Weight = 186 gms Initial Volume = 186 ml			SAMPLE NO. 8 Initial Weight = 183 gms Initial Volume = 183 ml			SAMPLE NO. 9 Initial Weight = 247 gms Initial Volume = 247 ml		
	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)
11/1/76	1412	INITIAL		1413	INITIAL		1414	INITIAL	
11/1/76	1421	25.0	87	1422	25.0	66	1423	25.0	77
11/2/76	0916	21.1	416	0916	21.1	386	0917	21.1	386
11/3/76	0839	21.5	483	0839	21.5	447	0839	21.5	447
11/4/76	0845	21.5	500	0845	21.5	459	0845	21.5	471
11/5/76	0947	22.0	505	0947	22.0	465	0947	22.0	460
11/6/76	1224	24.0	542	1224	24.0	497	1224	24.0	503
11/8/76	1657	21.5	499	1657	21.5	457	1657	21.5	473
11/10/76	1238	22.0	494	1238	22.0	499	1238	22.0	488
11/11/76	1635	22.5	526	1635	22.5	505	1635	22.5	494
11/12/76	0955	22.5	488	0955	22.5	473	0955	22.5	463
11/15/76	1450	20.5	536	1450	20.5	502	1450	20.5	473
11/18/76	0945	20.5	544	0945	20.5	497	0945	20.5	521
11/23/76	1004	21.0	543	1004	21.0	509	1004	21.0	509
11/30/76	1050	21.0	557	1055	21.0	518	1057	21.0	531
12/2/76	1212	23.8	562	1213	23.8	530	1214	23.8	540
12/7/76	1110	20.1	540	1111	20.0	497	1112	20.0	497
12/16/76	1529	23.9	542	1529	23.9	532	1529	23.9	542
12/16/76	WATER CHANGED								
12/20/76	1608	24.8	186	1610	24.0	181	1612	24.0	150
12/21/76	0913	24.0	202	0914	24.0	197	0916	24.0	173
12/22/76	0850	22.0	209	0851	21.8	204	0852	21.8	187
12/23/76	1334	21.8	219	1335	21.8	213	1336	21.8	195
12/28/76	0831	21.7	232	0832	21.7	223	0833	21.7	210
1/3/77	1400	22.2	248	1401	22.2	239	1402	22.2	230
1/11/77	0929	22.0	268	0930	22.0	257	0931	22.0	245
1/18/77	1051	22.0	269	1053	22.0	260	1054	22.0	247
1/27/77	0942	22.0	278	0943	22.0	267	0944	22.0	256

Table D-1. Continued.

SOURCE: Middle Site, Coal Creek

CONTROL GROUP

Date	SAMPLE NO. 10 Initial Weight = 208 gms Initial Volume = 208 ml			SAMPLE NO. 11 Initial Weight = 222 gms Initial Volume = 222 ml			SAMPLE NO. 12 Initial Weight = Initial Volume =		
	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)
11/1/76	1415	------INITIAL------		1416	------INITIAL------		1416	------INITIAL------	
11/1/76	1424	25.0	88	1424	25.0	74	1425	25.0	85
11/2/76	0914	21.1	725	0915	21.1	784	0915	21.1	743
11/3/76	0841	21.5	895	0841	21.5	942	0841	21.5	883
11/4/76	0849	21.5	907	0849	21.5	954	0849	21.5	907
11/5/76	0951	22.0	931	0951	22.0	976	0951	22.0	931
11/6/76	1230	24.0	1006	1230	24.0	1061	1230	24.0	1006
11/8/76	1700	21.5	924	1700	21.5	988	1700	21.5	935
11/10/76	1241	22.0	936	1241	22.0	1053	1241	22.0	997
11/11/76	1637	22.5	987	1637	22.5	1064	1637	22.5	1009
11/12/76	0958	22.5	925	0958	22.5	1003	0958	22.5	967
11/15/76	1452	20.5	1015	1452	20.5	1095	1452	20.5	1038
11/18/76	0948	20.5	1018	0948	20.5	1122	0948	20.5	1052
11/23/76	1007	21.0	1029	1007	21.0	1130	1007	21.0	1063
11/30/76	1059	21.0	1058	1100	21.0	1170	1102	21.0	1080
12/2/76	1217	23.8	1086	1219	23.8	1189	1220	23.5	1110
12/7/76	1116	20.0	1048	1117	20.0	1081	1118	20.0	1060
12/16/76	1537	23.1	1062	1537	23.1	1166	1537	23.1	1145
12/16/76	------------------			----WATER CHANGED----			------------------		
12/20/76	1614	24.0	317	1616	24.0	316	1617	24.0	276
12/21/76	0919	24.0	345	0920	24.0	354	0922	24.0	321
12/22/76	0855	22.0	367	0856	22.0	377	0857	22.0	348
12/23/76	1337	22.0	378	1338	22.0	391	1339	22.0	363
12/28/76	0835	21.7	406	0836	21.7	425	0837	21.7	390
1/3/77	1405	22.0	444	1406	22.0	464	1407	22.0	437
1/1/77	0933	22.2	481	0934	22.2	509	0935	22.2	470
1/18/77	1056	22.0	492	1057	22.0	528	1058	22.0	487
1/27/77	0946	22.0	504	0947	22.0	541	0948	22.0	502

Table D-2. Saturation dissolution data, samples rinsed and dried.

SOURCE: Experimental Channel, 20 Ft. above probes and 3/4 Ft above channel bottom.

EXPERIMENTAL GROUP

Date	SAMPLE NO. 13 Initial Weight = 342.4 gms Initial Volume = 342.4 ml			SAMPLE NO. 14 Initial Weight = 379.2 gms Initial Volume = 379.2 ml			SAMPLE NO. 15 Initial Weight = 330 gms Initial Volume = 330 ml		
	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @25°C)
11/2/76	1547			1548			1550		
11/2/76	1610	25	307	1613	25	341	1614	25.0	379
11/3/76	0851	21.5	854	0852	21.5	871	0852	21.5	968
11/3/76	0855	21.5	1072	0855	21.5	1130	0855	21.5	1236
11/5/76	0955	22.0	1189	0955	22.0	1200	0955	22.0	1267
11/9/76	------------SAMPLE RINSED------------			----DRIED--------NEW WATER ADDED------			----------------------------------		
	Weight: 340 gms		Volume: 340 ml	Weight: 376.4 gms		Volume: 376.4 ml	Weight: 327.6 gms		Volume: 327.6 ml
11/9/76	0930	23.0	95	0930	23.0	99	0930	23.0	115
11/9/76	1626	23.0	392	1626	23.0	391	1626	23.0	417
11/10/76	1219	22.0	589	1219	22.0	632	1219	22.0	632
11/11/76	1532	22.0	743	1531	22.0	743	1531	22.0	720
11/12/76	1001	22.5	730	1001	22.5	746	1001	22.5	693
11/15/76	1456	20.5	842	1456	20.5	830	1456	20.5	784
11/18/76	0952	20.5	891	0952	20.5	867	0952	20.5	832
11/23/76	1010	20.5	927	1010	20.5	921	1010	20.5	892
11/30/76	1103	21.0	956	1105	21.0	962	1107	21.0	923
12/01/76	1222	23.0	973	1224	23.0	990	1349	23.0	957
12/07/76	1120	19.2	954	1121	19.0	947	1122	18.5	913
12/20/76	0908	21.5	1095	0910	21.4	1069	0912	21.4	1030
12/2/76	1450 ------------SAMPLE RINSED--------			-----DRIED--------------NEW WATER ADDED			----------------------------------		
	Weight: 337.3 gms		Volume: 337.3 ml	Weight: 375.2 gms		Volume: 375.2 ml	Weight: 327.0 gms		Volume: 327 ml
12/21/76	1556	22.2	163	1557	22.4	120	1557	22.0	147
12/22/76	0901	22.0	312	0902	22.0	250	0903	22.0	328
12/23/76	1340	22.0	400	1341	22.0	347	1342	22.0	441
12/28/76	0840	21.7	486	0841	21.7	412	0842	21.7	497
1/3/77	1410	21.8	577	1411	21.3	502	1412	21.0	593
1/11/77	0938	22.2	649	0939	22.2	586	0940	22.2	660
1/18/77	1102	22.0	686	1103	22.0	618	1104	22.0	697
1/27/77	0951	22.0	740	0952	22.0	640	0953	22.0	745

Table D-2. Continued.

SOURCE: Above Spring, Coal Creek

EXPERIMENTAL GROUP

Date	SAMPLE NO. 16 Initial Weight = 359.7 gms Initial Volume = 359.7 ml			SAMPLE NO. 17 Initial Weight = 374.1 gms Initial Volume = 374.1 ml			SAMPLE NO. 18 Initial Weight = 398.3 gms Initial Volume = 348.3 ml		
	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @25°C)
11/2/76	1551			1552			1553		
11/2/76	1615	25.0	83	1617	25.0	96	1618	25.0	96
11/3/76	0856	21.5	300	0856	21.5	330	0856	21.5	324
11/4/76	0859	21.5	447	0859	21.5	489	0859	21.5	483
11/5/76	1017	22.0	521	1017	22.0	572	1017	22.0	550
11/9/76	---SAMPLE RINSED---			--- DRIED ---			---NEW WATER ADDED---		
	Weight: 358 gms	Volume: 358 ml		Weight: 373.9 gms	Volume 378.9 ml		Weight: 897 gms	Volume: 397 ml	
11/9/76	0929	23.0	43	0929	23.0	48	0929	23.0	53
11/9/76	1631	23.0	144	1631	23.0	152	1631	23.0	167
11/10/76	1222	22.0	305	1222	22.0	332	1222	22.0	299
11/11/76	1536	22.0	443	1536	22.0	438	1536	22.0	410
11/12/76	1005	22.5	463	1005	22.5	463	1005	22.5	432
11/15/76	1503	20.5	577	1503	20.5	646	1503	20.5	611
11/18/76	0956	20.5	642	0956	20.5	;28	0956	20.5	693
11/23/76	1014	20.0	728	1014	20.0	844	1014	20.0	786
11/30/76	1108	21.0	771	1110	21.0	906	1111	21.0	850
12/02/76	1350	23.0	803	1353	23.0	962	1354	23.0	885
12/07/76	1123	18.5	776	1125	18.5	925	1126	18.2	861
12/20/76	0914	21.4	873	0926	21.5	976	0928	21.5	966
12/21/76	1505 ---SAMPLE RINSED---			---DRIED---			---NEW WATER ADDED---		
	Weight: 357.4 gms	Volume: 357.4 ml		Weight: 373.7 gms	Volume: 373.7 ml		Weight: 396.8 gms	Volume: 396.8 ml	
12/21/76	1558	22.0	63	1601	21.2	56	1602	21.4	73
12/22/76	0907	22.0	202	0908	22.0	198	0909	22.0	217
12/23/76	1344	22.0	314	1345	22.0	330	1346	22.0	327
12/28/76	0845	21.7	451	0846	21.7	508	0846	21.7	452
1/3/77	1414	21.0	531	1415	21.0	616	1416	21.0	540
1/11/77	0943	22.2	582	0944	22.2	671	0945	22.2	593
1/18/77	1107	22.0	584	1107	22.0	686	1108	22.0	606
1/27/77	0957	22.0	618	0958	22.0	707	0959	22.0	638

Table D-2. Continued.

SOURCE: Lower Site, Coal Creek

EXPERIMENTAL GROUP

Date	SAMPLE NO. 19 Initial Weight = 219.9 gms Initial Volume = 219.9 ml Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	SAMPLE NO. 20 Initial Weight = 173.7 gms Initial Volume = 173.7 ml Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	SAMPLE NO. 21 Initial Weight = 248.3 gms Initial Volume = 248.3 ml Time (MST	Temperature °C	Conductivity (umhos @25°C)
11/2/76	1554			1557			1558		
11/2/76	1619	25.0	127	1620	25.0	175	1620	25.0	138
11/3/76	0858	21.5	377	0858	21.5	430	0858	21.5	365
11/4/76	0903	21.5	465	0903	21.5	518	0903	21.5	447
11/5/76	1021	22.0	488	1021	22.0	533	1021	22.0	471
11/9/76	SAMPLE RINSED			DRIED			NEW WATER ADDED		
	Weight: 205.6 gms	Volume: 205.6 ml		Weight: 167.7 gms	Volume: 167.7 ml		Weight: 239.6 gms	Volume: 289.6 ml	
11/9/76	0925	23.0	113	0925	23.0	108	0925	23.0	113
11/9/76	1640	23.0	211	1640	23.0	206	1620	23.0	206
11/10/76	1225	22.0	252	1225	22.0	249	1225	22.0	249
11/11/76	1539	22.0	277	1539	22.0	277	1539	22.0	277
11/12/76	1008	22.5	262	1008	22.5	262	1008	22.5	161
11/15/76	1505	20.5	283	1505	20.5	265	1505	20.5	294
11/18/76	0959	20.5	286	0959	20.5	300	0959	20.5	306
11/23/76	1017	20.5	315	1017	20.5	309	1017	20.5	315
11/30/76	1113	21.0	338	1114	21.0	338	1115	21.0	332
12/02/76	1356	23.2	332	1358	23.2	334	1401	23.2	334
12/07/76	1127	19.0	316	1128	18.5	308	1131	18.5	312
12/20/76	0930	21.5	341	0932	21.5	335	0944	22.0	337
12/21/76	1530 SAMPLE RINSED			DRIED			NEW WATER ADDED		
	Weight: 202.4 gms	Volume 202.4 ml		Weight: 162.3 gms	Volume:162.3 ml		Weight: 231.3 gms	Volume: 231.3 ml	
12/21/76	1603	22.0	108	1604	22.0	127	1606	22.0	98
12/22/76	0913	22.0	168	0914	22.0	187	0916	22.0	145
12/23/76	1347	22.0	197	1347	22.0	219	1348	22.0	171
12/28/76	0849	21.7	230	0850	21.7	243	0851	21.7	194
1/3/77	1419	21.8	253	1420	21.2	268	1421	21.2	230
1/11/77	0947	22.2	275	0948	22.2	282	0949	22.3	250
1/18/77	1111	22.0	280	1112	22.0	288	1113	22.0	255
1/27/77	1002	22.0	287	1003	22.0	290	1004	22.0	263

Table D-2. Continued.

EXPERIMENTAL GROUP — SOURCE: Middle Site, Coal Creek

Date	SAMPLE NO. 22 Initial Weight = 185.4 gms Initial Volume = 185.4 ml			SAMPLE NO. 23 Initial Weight = 218.1 gms Initial Volume = 218.1 ml			SAMPLE NO. 24 Initial Weight = 240.3 gms Initial Volume = 240.3 ml		
	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)	Time (MST)	Temperature °C	Conductivity (umhos @ 25°C)
11/2/76	1600			1601			1602		
11/2/76	1621	25	175	1622	25	151	1623	25	163
11/3/76	0900	21.5	824	0900	21.5	754	0900	21.5	754
11/4/76	0906	21.5	1013	0906	21.5	954	0906	21.5	977
11/5/76	1025	22	1020	1025	22	976	1025	22	1021
11/9/76	----------SAMPLE RINSED--			----------DRIED----------			--------NEW WATER ADDED--------		
	Weight: 180.5 gms Volume: 180.5 ml			Weight: 211.2 gms Volume: 211 ml			Weight: 235.1 gms Volume: 235 ml		
11/9/76	0923	23	239	0923	23	206	0923	23	247
11/9/76	1643	23	424	1643	23	381	1643	23	463
11/10/76	1229	22	554	1229	22	565	1229	22	654
11/11/76	1542	22	621	1541	22	598	1541	22	709
11/12/76	1011	22.5	596	1011	22.5	576	1012	22.5	679
11/15/76	1507	20.5	623	1507	20.5	646	1507	20.5	726
11/18/76	1002	20.5	648	1002	20.5	670	1002	20.5	763
11/23/76	1021	20	671	1021	20	705	1021	20	809
11/30/76	1116	21	709	1118	21	720	1120	21	838
12/2/76	1402	23	693	1403	23	753	1405	23	869
12/7/76	1132	18.2	649	1133	18	704	1134	18	831
12/20/76	0946	21.8	693	0948	21.8	776	0950	21.8	920
12/21/76	1535 ----------SAMPLE RINSED--			----------DRIED----------			--------NEW WATER ADDED--------		
	Weight: 163.9 gms Volume: 163.9 ml			Weight: 206.8 gms Volume: 206.8 ml			Weight: 231.3 gms Volume: 231.3 ml		
12/21/76	1607	20	201	1608	20	156	1609	20.5	206
12/22/76	0919	22	334	0920	22	278	0921	22	358
12/23/76	1349	22	382	1349	22	354	1350	22	441
12/28/76	0854	21.7	422	0855	21.7	418	0856	21.7	497
1/3/77	1424	21	457	1425	21	469	1425	21	550
1/11/77	0953	22.2	489	0954	22.2	515	0955	22.2	602
1/18/77	1115	22	494	1116	22	529	1117	22	619
1/27/77	1006	22	502	1007	22	541	1007	22	640

Table D-3. Rotoevaporator dissolution results.

	GRAIN SIZE I	II	III	IV	
PASSED	3/8	#4	#10	#20	
RETAINED	#4	#10	#20	#60	Cycle
	Specific conductance (μmhos/cm @ 25°C)				No.
	515	408	561	718	0
	735	544	647	800	1
	722	564	712	801	2
	667	699	655	700	3
Site 1	719	676	640	--	4
	703	704	742	--	5
	--	873	688	--	6
	--	753	--	--	7
	748	655	902	1397	0
	867	808	951	1651	1
	804	779	905	1598	2
Site 2	747	698	910	1528	3
	744	926	920	1410	4
	735	989	--	--	5
	--	717	--	--	6
	--	--	349	639	0
	--	--	439	684	1
Site 3	--	--	411	630	2
	--	--	--	723	3
	--	--	--	635	4
	--	--	--	638	5

Table D-4. Power function coefficients for dissolution from different grain sizes in quiescent water.

	GRAIN SIZE				
PASSED	3/8	#4	#10	#20	Time
RETAINED	#4	#10	#20	#60	(Hours)
	Specific conductance (μmhos/cm @ 25°C)				
	192	218	266	538	.008333
	270	315	509	743	.08333
	399	585	705	804	.5
Site 1	756	826	759	872	8
	930	906	782	894	24
	956	881	1045	1046	72
	a=466.31	a=522.87	a=603.98	a=787.36	
	b=.192	b=.165	b=.127	b=.061	
	r^2=.987	r^2=.936	r^2=.87	r^2=.90	
	275	249	419	765	.00833
	367	390	624	844	.0833
	459	552	726	1013	.5
Site 2	610	634	821	1213	8
	784	736	797	1536	24
	817	825	883	1332	72
	a=496.22	a=507.01	a=678.91	a=1063.40	
	b=.123	b=.124	b=.072	b=.074	
	r^2=.992	r^2=.951	r^2=.866	r^2=.92	
	168	174	291	490	.00833
	225	257	442	607	.0833
	308	410	537	666	.5
Site 3	482	749	524	620	8
	578	621	632	725	24
	740	653	705	795	72
	a=350.64	a=403.96	a=491.82	a=636.07	
	b=.163	b=.158	b=.083	b=.042	
	r^2=.996	r^2=.910	r^2=.878	r^2=.805	
	166	184	309	649	.00833
	252	245	431	724	.0833
	338	364	601	1022	.5
Site	366	369	1062	1463	8
	439	447	847	1949	24
	507	524	1215	2270	72
	a=314.42	a=325.95	a=641.05	a=1163.08	
	b=.112	b=.107	b=.148	b=.145	
	r^2=.947	r^2=.936	r^2=.945	r^2=.923	

Concentration fit to the power function $C = at^b$

$\bar{X}$=755.00	$\bar{X}$=720.75	$\bar{X}$=962	$\bar{X}$=1360.75
S=187.95	S=163.14	S=218.47	S=644.65

Table D-5. Macrochannel sediment results (8/26/76) (sediment dried then D. W. as added on a 1 to 1 basis.)

Flume No. 1 Sediment Wt: 414.68 gms Sample taken: 0830 MST		Flume No. 2 Sediment Wt: 485.16 gms Sample taken: 0835 MST		Flume No. 3 Sediment Wt: Sample taken:		Flume No. 4 Sediment Wt: 470.4 gms Sample taken: 0840 MST	
Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C
0	0	0	0		Not Enought Sediment Taken	0	0
.77	1993	.85	1116			.85	854
26.83	2591	26.83	1625			26.83	1437
119.47	2808	119.47	2059			119.77	1809
287.92	2767	287.83	2209			287.55	1981
336.42	2861	336.37	2397			336.77	2100
455.88	2804	455.88	2329			456.20	2106
815.40	2955	815.35	2583			815.65	2439
988.65	2875	988.68	2555			989.02	2423

Table D-5. Continued.

Flume No. 1 Sediment Wt: 414.68 gms Sample taken: 0830 MST		Flume No. 2 Sediment Wt: 485.16 gms Sample taken: 0835 MST		Flume No. 3 Sediment Wt: Sample taken:		Flume No. 4 Sediment Wt: 470.4 gms Sample taken: 0840 MST	
Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C
0	0	0	0	0	0	0	0
.85	866	.77	558	.85	638	.85	723
26.83	1460	26.83	1189	26.83	848	26.80	1201
119.47	1850	119.97	1642	119.63	950	119.48	1526
287.87	2115	287.75	1834	288.02	1035	287.85	1958
336.68	2318	336.95	1990	336.55	1111	336.48	1979
455.90	2173	456.43	2032	456.05	1082	455.90	2053
815.37	2359	815.85	2356	815.50	1142	815.37	2405
988.62	2323	989.30	2355	988.85	1090	988.70	2379

Table D-5. Continued.

Flume No. 1 Sediment Wt: 337.8 gms		Flume No. 2 Sediment Wt: 420.4 gms		Flume No. 3 Sediment Wt: 352.1 gms		Flume No. 4 Sediment Wt: 320.5 gms	
Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C	Time (hrs)	Cond. μmhos@25^{o}C
0	0	0	0	0	0	0	0
.85	752	.85	689	.85	1071	.85	1002
26.87	1189	26.83	1366	26.83	1460	26.83	1637
119.72	1596	120.55	1730	119.45	1650	119.85	1977
287.52	1662	287.32	2003	287.83	1722	287.67	2149
336.70	1705	336.55	2133	336.46	1770	336.83	2254
456.18	1731	455.98	2140	455.90	1733	456.33	2210
815.58	1938	815.43	2527	815.36	1864	815.73	2510
986.98	1906	988.80	2471	988.71	1817	989.18	2467

Table D-5. Continued.

Flume No. 1 Sample Wt: 418.7 gms Sample taken: 0830 MST		Flume No. 2 Sediment Wt: 512.5 gms Sample Taken: 0835 MST		Flume No. 3 Sample taken:		Flume No. 4 Sediment Wt: 504.9 gms Sample taken: 0840 MST	
Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C
0	0	0	0		Not Enough Sediment Taken	0	0
22.33	841	22.30	819			21.68	692
93.20	1160	93.33	1149			92.85	1021
101.28	1439	101.45	1296			100.92	1189
118.82	1415	118.82	1354			118.28	1213
125.35	1445	125.45	1505			124.93	1373
165.43	1676	165.50	2093			164.98	1807
188.88	1686	188.95	1818			188.40	1637
285.32	1815	285.42	1851			284.97	1815

Table D-5. Continued.

Flume No. 1 Sediment Wt: 326.8 gms Sample taken: 11:45-1235 MST		Flume No. 2 Sediment Wt: 310.3 gms Sample taken: 1150-1200 MST		Flume No. 3 Sediment Wt: 315.8 gms Sample taken: 1210-1220 MST		Flume No. 4 Sediment Wt: 438.9 gms Sample taken: 1215-1225 MST	
Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C
0	0	0	0	0	0	0	0
18.47	406	18.58	363	18.42	271	18.25	489
89.62	724	89.63	787	89.67	436	89.47	851
97.25	856	97.72	1070	97.42	501	97.08	975
114.83	856	115.12	1308	114.93	511	114.63	1070
121.52	867	121.73	1421	121.62	494	121.33	1096
161.68	868	161.77	1760	161.72	523	161.45	1486
185.13	879	185.08	1686	185.17	542	184.95	1445
281.77	999	281.82	1705	281.85	583	281.63	1583

Table D-5. Continued.

Flume No. 1 Sediment Wt: 328.5 gms		Flume No. 2 Sediment Wt: 382.4 gms		Flume No. 3 Sediment Wt: 345.3 gms		Flume No. 4 Sediment Wt: 303.5 gms	
Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C	Time (hrs)	Cond. µmhos@25°C
0	165	0	265	0	146	0	52
.17	190	.17	260	.17	146	.17	96
3.47	281	3.38	342	3.33	291	3.15	270
47.67	710	47.48	853	47.48	771	47.27	764
79.62	828	79.53	1218	79.48	877	79.30	840
93.03	865	92.95	1389	92.90	914	92.72	938
118.08	987	118.00	1742	117.95	974	117.77	1121
141.28	1023	141.20	1862	141.15	986	140.97	1134
165.12	1096	165.03	1937	164.98	1047	164.80	1206
189.12	1133	189.03	1888	188.98	1011	188.80	1181
261.03	1183	260.95	1989	260.90	1021	260.72	1236
290.87	1163	290.78	2011	290.73	1043	290.55	1207
336.62	1183	336.53	2161	336.48	1086	336.30	1312
360.03	1193	359.95	2142	359.90	1071	359.72	1275
432.37	1207	432.28	2219	432.23	1125	432.05	1321

Table D-6. Least squares regression analysis of Equation 4.3.

Location	Grain Size Passed	Grain Size Retained	K_1	r_1^2	Limit hours	K_2	r_2^2
Site 1	3/8	# 4	.000321	.996	9.00	.000065	.760
Site 1	# 4	#10	.000580	.996	6.81	.000033	.605
Site 1	#10	#20	.000651	.930	4.06	.000051	.913
Site 1	#20	#60	.000374	.766	4.82	.000029	.960
Site 2	3/8	# 4	.000275	.957	6.72	.000045	.857
Site 2	# 4	#10	.000458	.974	5.49	.000034	.978
Site 2	#10	#20	.000442	.851	5.41	.000017	.822
Site 2	#20	#60	.000388	.999	7.80	.000042	.430
Site 3	3/8	# 4	.000216	.990	8.76	.000044	.999
Site 3	# 4	#10	.000366	.999	11.94	-.000014	.367
Site 3	#10	#20	.000360	.892	4.64	.000023	.884
Site 3	#20	#30	.000253	.854	4.00	.000019	.754
Site 4	3/8	# 4	.000257	.959	5.11	.000022	.979
Site 4	# 4	#10	.000282	.999	4.99	.000021	.941
Site 4	#10	#20	.000445	.988	7.36	.000062	.646
Site 4	#20	#60	.000599	.984	7.08	.000155	.952

APPENDIX E

LISTINGS OF THE HYDROLOGIC/SALINITY MODELS

Table E-1.a. The stochastic rainfall subroutine (RAIN).

```
      SUBROUTINE RAIN
      COMMON/BLK1/XKV(12),BV(12),BT1(12,5),BT2(12,5),XKT1(12,5),
     1XKT2(12,5),DECIS(12,5),XKNS(12),BNS(12),IDUM,A,B,C,H1,H2,H3,
     1H4,H5,TOTPRE,CHANCE,TELIM
     5/BLK5/PRECIP(5),TIME
     */BLK10/MON
      DIMENSION P(27),R(27)
      DATA P/.0001,.0005,.0010,.0050,.0100,.0200,.0250,.0400,.0500,
     *.1000,.2000,.3000,.4000,.5000,.6000,.7000,.8000,.9000,.9500,.9600,
     *.9750,.9800,.9900,.9950,.9990,.9995,.9999/
      DATA R/3.71902,3.29053,3.09023,2.57583,2.32635,2.05375,1.95996,
     *1.75069,1.64485,1.28155,.84162,.52440,.25335,.00000,-.25335,-.524
     *40,-.84162,-1.28155,-1.64485,-1.75069,-1.95996,-2.05375,-2.32635,
     *-2.57583,-3.09023,-3.29053,-3.71902/
      TOTPRE=0.
C     DETERMINE WHETHER OR NOT A STORM OCCURS
      PRS=RANDOM(IDUM)
      IF(PRS.GT.CHANCE) GO TO 500
C     DETERMINE STORM DEPTH
      PRV=RANDOM(IDUM)
      XV=RLANGR(PRV,P,R)
      VOL=10.**(ALOG10(BV(MON))+XV*XKV(MON))
C     DETERMINE STORM DURATION
      LV=1
      IF(VOL.GE..1) LV=2
      IF(VOL.GE..2) LV=3
      IF(VOL.GE..4) LV=4
      IF(VOL.GE..6) LV=5
      PRT=RANDOM(IDUM)
      IF(PRT.LT.DECIS(MON,LV)) GO TO 5
      TIME=BT2(MON,LV)+XKT2(MON,LV)*(-ALOG(-ALOG(PRT)))
      GO TO 6
    5 TIME=BT1(MON,LV)+XKT1(MON,LV)*(-ALOG(-ALOG(PRT)))
    6 CONTINUE
      TIME=ABS(TIME)
      IF(VOL/TIME.GT.TELIM) TIME=VOL/TELIM
C     CALCULATE HYETOGRAPH
      PRECIP(1)=H1*VOL
      PRECIP(2)=H2*VOL
      PRECIP(3)=H3*VOL
      PRECIP(4)=H4*VOL
      PRECIP(5)=H5*VOL
      TOTPRE=(H1+H2+H3+H4+H5)*VOL
  500 CONTINUE
      RETURN
      END
3 END
```

Table E-1.b. A sample of rainfall data generated by RAIN.

Date	Duration (Hours)	Precipitation (inches)	Runoff (inches)
4/9	1.13	0.16	0.00
4/10	1.910	0.410	0.00
		0.041	0.000
		0.103	0.000
		0.124	0.005
		0.104	0.000
		0.041	0.000
4/11	0.51	0.06	0.00
4/13	2.00	0.54	0.01
		0.054	0.000
		0.136	0.010
		0.163	0.000
		0.136	0.000
		0.054	0.000
4/29	4.00	0.12	0.00
7/03	0.06	0.09	0.03
		0.009	0.000
		0.021	0.000
		0.026	0.004
		0.021	0.019
		0.009	0.007
7/14	0.80	0.10	0.00
7/18	0.08	0.09	0.03
		0.009	0.000
		0.022	0.000
		0.026	0.004
		0.022	0.019
		0.009	0.006
7/19	0.57	0.46	0.26
		0.046	0.000
		0.116	0.090
		0.139	0.100
		0.116	0.066
		0.046	0.000
7/21	0.56	0.04	0.00
7/23	0.15	0.03	0.00
7/16	0.52	0.10	0.01
		0.010	0.000
		0.025	0.000
		0.031	0.000
		0.025	0.006
		0.010	0.000

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (inches)	Runoff (inches)
8/1	0.14	0.08	0.02
		0.008	0.000
		0.021	0.000
		0.025	0.001
		0.021	0.016
		0.008	0.002
8/3	0.80	0.04	0.00
8/4	0.76	0.11	0.00
8/8	0.53	0.66	0.44
		0.006	0.000
		0.165	0.144
		0.198	0.162
		0.165	0.120
		0.066	0.015
8/9	1.79	0.16	0.00
8/22	0.41	0.03	0.00
8/26	0.07	0.04	0.00
8/30	3.14	0.32	0.00
9/25	1.22	0.27	0.02
		0.027	0.000
		0.067	0.000
		0.080	0.016
		0.067	0.000
		0.027	0.000
10/1	4.52	0.28	0.00
10/29	0.10	0.16	0.09
		0.016	0.000
		0.039	0.002
		0.047	0.043
		0.039	0.035
		0.016	0.011
10/30	0.55	0.17	0.03
		0.017	0.000
		0.041	0.000
		0.050	0.028
		0.041	0.004
		0.017	0.000
4/8	0.68	0.26	0.05
		0.026	0.000
		0.066	0.014
		0.079	0.029
		0.066	0.003
		0.026	0.000

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (Inches)	Runoff (Inches)
4/14	0.75	0.07	0.00
4/15	3.50	0.22	0.00
4/20	0.09	0.07	0.01
		0.007	0.000
		0.017	0.000
		0.021	0.000
		0.017	0.010
		0.007	0.004
4/27	0.09	0.08	0.03
		0.008	0.000
		0.021	0.000
		0.025	0.002
		0.021	0.018
		0.008	0.005
5/6	0.63	0.04	0.00
5/21	0.17	0.07	0.01
		0.007	0.000
		0.18	0.000
		0.022	0.000
		0.018	0.011
		0.007	0.001
5/29	0.17	0.22	0.14
		0.022	0.000
		0.056	0.023
		0.067	0.060
		0.056	0.048
		0.022	0.013
6/11	1.12	0.79	0.35
		0.079	0.000
		0.198	0.140
		0.237	0.135
		0.198	0.077
		0.079	0.000
6/17	0.38	0.01	0.00
6/19	0.28	0.12	0.03
		0.012	0.000
		0.029	0.000
		0.035	0.017
		0.029	0.016
		0.012	0.000

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (inches)	Runoff (inches)
6/28	0.68	0.18	0.03
		0.018	0.000
		0.045	0.000
		0.054	0.026
		0.045	0.000
		0.018	0.000
6/30	0.08	0.07	0.02
		0.007	0.000
		0.018	0.000
		0.021	0.000
		0.018	0.012
		0.007	0.005
7/5	1.03	0.37	0.05
		0.037	0.000
		0.092	0.030
		0.111	0.020
		0.092	0.000
		0.037	0.000
7/11	0.07	0.08	0.02
		0.008	0.000
		0.019	0.000
		0.023	0.000
		0.019	0.016
		0.008	0.006
7/13	0.47	0.67	0.45
		0.067	0.001
		0.168	0.138
		0.202	0.164
		0.168	0.125
		0.067	0.021
7/16	0.06	0.08	0.02
		0.008	0.000
		0.020	0.000
		0.024	0.000
		0.020	0.018
		0.008	0.006
7/22	0.23	0.03	0.00
7/23	0.73	0.13	0.00
		0.013	0.000
		0.032	0.000
		0.039	0.003
		0.032	0.000
		0.013	0.000

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (Inches)	Runoff (Inches)
7/24	0.39	0.58	0.43
		0.058	0.000
		0.146	0.132
		0.175	0.153
		0.146	0.117
		0.058	0.026
7/25	1.07	0.07	0.00
8/6	2.27	0.06	0.00
8/7	0.90	0.24	0.03
		0.024	0.000
		0.060	0.000
		0.072	0.030
		0.060	0.000
		0.024	0.000
8/12	0.10	0.16	0.09
		0.016	0.000
		0.039	0.002
		0.047	0.044
		0.039	0.035
		0.016	0.011
8/17	0.44	0.17	0.05
		0.017	0.000
		0.043	0.000
		0.051	0.036
		0.043	0.016
		0.017	0.000
8/20	0.08	0.07	0.01
		0.007	0.000
		0.017	0.000
		0.021	0.000
		0.017	0.010
		0.007	0.004
9/9	4.06	0.23	0.00
9/10	0.42	0.13	0.03
		0.013	0.000
		0.032	0.000
		0.039	0.019
		0.032	0.007
		0.013	0.000
9/28	2.82	0.23	0.00
10/2	8/73	1.26	0.00

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (Inches)	Runoff (Inches)
10/5	1.04	0.19	0.00
		0.19	0.02
		0.019	0.000
		0.048	0.000
		0.057	0.019
		0.048	0.000
		0.019	0.000
10/13	1.92	0.30	0.00
10/4	2.94	2.88	1.28
		0.288	0.023
		0.720	0.377
		0.864	0.511
		0.720	0.368
		0.288	0.000
10/28	0.17	0.19	0.10
		0.019	0.000
		0.046	0.007
		0.056	0.046
		0.046	0.036
		0.019	0.007
5/1	1.43	0.09	0.00
5/7	0.35	0.02	0.00
5/8	0.30	0.03	0.00
5/19	0.35	0.12	0.02
		0.012	0.000
		0.029	0.000
		0.035	0.014
		0.029	0.010
		0.012	0.000
5/20	0.11	0.04	0.00
5/24	2.10	0.22	0.00
5/25	0.36	0.08	0.01
		0.008	0.000
		0.020	0.000
		0.024	0.000
		0.020	0.008
		0.008	0.000
6/3	0.73	0.15	0.01
		0.015	0.000
		0.038	0.000
		0.045	0.014
		0.038	0.000
		0.015	0.000
6/8	1.31	0.21	0.00

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (Inches)	Runoff (Inches)
6/12	0.08	0.12	0.06
		0.012	0.000
		0.029	0.000
		0.035	0.024
		0.029	0.027
		0.012	0.009
6/20	0.41	0.02	0.00
6/24	3.01	0.45	0.00
6/29	0.57	0.10	0.00
		0.010	0.000
		0.025	0.000
		0.030	0.000
		0.025	0.003
		0.010	0.000
6/30	0.29	0.43	0.32
		0.043	0.000
		0.107	0.091
		0.129	0.115
		0.107	0.090
		0.043	0.022
7/4	0.77	0.02	0.00
7/6	0.32	0.04	0.00
7/7	0.37	0.40	0.26
		0.040	0.000
		0.101	0.078
		0.121	0.100
		0.101	0.074
		0.040	0.009
7/8	1.46	0.22	0.00
7/12	0.17	0.18	0.10
		0.018	0.000
		0.046	0.009
		0.055	0.048
		0.046	0.037
		0.018	0.008
7/13	0.24	0.25	0.15
		0.025	0.000
		0.062	0.030
		0.074	0.064
		0.062	0.049
		0.025	0.009

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (Inches)	Runoff (Inches)
7/19	0.53	0.16	0.03
		0.016	0.000
		0.040	0.000
		0.048	0.028
		0.040	0.005
		0.016	0.000
7/22	0.09	0.08	0.02
		0.008	0.000
		0.019	0.000
		0.023	0.000
		0.019	0.016
		0.008	0.005
7/23	0.86	0.06	0.00
7/24	0.10	0.03	0.00
7/25	0.11	0.08	0.02
		0.008	0.000
		0.020	0.000
		0.025	0.001
		0.020	0.017
		0.008	0.004
7/31	0.88	0.02	0.00
8/11	0.29	0.03	0.00
8/20	0.69	0.25	0.03
		0.025	0.000
		0.063	0.009
		0.075	0.024
		0.063	0.000
		0.025	0.000
8/30	2.48	0.29	0.00
9/16	0.53	0.06	0.00
9/17	0.92	0.09	0.00
9/18	0.70	0.04	0.00
9/20	0.07	0.10	0.04
		0.010	0.000
		0.025	0.000
		0.030	0.012
		0.025	0.023
		0.010	0.008
10/5	0.89	0.42	0.13
		0.042	0.000
		0.106	0.057
		0.127	0.053
		0.106	0.016
		0.042	0.000

Table E-1.b. Continued.

Date	Duration (Hours)	Precipitation (Inches)	Runoff (Inches)
10/6	3.52	0.21	0.00
10/7	12.63	1.04	0.00
10/8	0.83	0.51	0.17
		0.051	0.000
		0.127	0.062
		0.152	0.070
		0.127	0.036
		0.051	0.000
10/11	14.37	0.97	0.00

Table E-1.c. Hydrologic extractions subroutine (HYDRGY), including the plant consumptive use subroutine (CONSUM).

```
      SUBROUTINE HYDRGY
      COMMON
     2/BLK2/RUNOFF(5),SS,SMOIS,WP
     4/BLK4/FC,FO,SI,DKT,SUMRO,TAUSW,RUNS
     5/BLK5/PRECIP(5),TIME
C
C     INITIALIZATION
      RUNS=0.
      RSW=0.
      IND=0
      FT=FO
      SFW=0.
      SUMPT=0.
      SIO=0.
      SUMSI=0.
      SUMSRO=0.
      SUMRO=0.
      DO 120 II=1,5
      PPT=PRECIP(II)
      SRO=0.
      RAIN=0.
      SIA=0.
      SUMPT=SUMPT+PPT
C
C     INTERCEPTION AND DEPRESSION STORAGE
      DSI=SI-SIO
      IF(PPT-DSI)52,53,54
   52 SIO=SIO+PPT
      SUMSI=SUMSI+PPT
      RAIN=0.
      SIA=PPT
      GO TO 55
   53 SIO=SI
      SUMSI=SUMSI+SI
      RAIN=0.
      SIA=SI
      GO TO 55
   54 SIO=SI
      SUMSI=SUMSI+DSI
      RAIN=PPT-DSI
      SIA=DSI
   55 CONTINUE
C
C     INFILTRATION
      RAIN=RAIN+RSW
      IF(IND.EQ.1) GO TO 99
      T=(ALOG((SS-SMOIS)/SS))/(-DKT)
      FTI=FC+(FO-FC)*EXP(-DKT*T)
      GO TO 98
   99 FTI=FTF
   98 T=T+TIME/5.
      FTF=FC+(FO-FC)*EXP(-DKT*T)
      FT=(FTI+FTF)/2.
      SFW=RAIN-FT*TIME/5.
      IF(SFW)64,64,66
C
C     SOIL MOISTURE STORAGE
   64 SMOIS=SMOIS+RAIN
      IF(SMOIS.GE.SS) SMOIS=SS-.01
      RSW=0.
      SFW=0.
      IND=0
      GO TO 83
   66 SMOIS=SMOIS+FT*TIME/5.
      IND=1
C
C     SURFACE WATER ROUTING
      IF(SMOIS.LE.SS) GO TO 171
      SFW=SFW+SMOIS-SS
      SMOIS=SS
  171 RSW=SFW*EXP(-TAUSW)
      SRO=SFW-RSW
      SUMSRO=SUMSRO+SRO
```

Table E-1.c. Continued.

```
      C
C        RUNOFF
   83 CONTINUE
         RUNOFF(II)=SRO
         SUMRO=SUMRO+RUNOFF(II)
         RUNS=RUNS+RUNOFF(II)
  120 CONTINUE
         RETURN
         END
```

```
         SUBROUTINE CONSUM
C
         COMMON
       2/BLK2/RUNOFF(5),SS,SMOIS,WP
       6/BLK6/XLAT,FICAP,JDAY,CT,AET,IFRF,IFPS,XKC1,XKC2,TX
       9/BLK9/TMON(12)
       */BLK10/MON
         CALL SUPFS(JDAY,XLAT,FS)
         CALL TEMF(JDAY,TEM)
         IF(JDAY.GT.IFPS.AND.JDAY.LT.IFRF) XKC=XKC2
         IF(JDAY.LE.IFPS.OR.JDAY.GE.IFRF) XKC=XKC1
         ETP=CT*(TEM-TX)*FS/(595.9-.305*(TMON(MON)-32.))
         ET=XKC*ETP/2.54
         AET=(ALOG((100.*(SMOIS-WP))/(FICAP-WP)+1.)/4.615)*ET
         SMOIS=SMOIS-AET
         IF(SMOIS.LT.WP) SMOIS=WP
         RETURN
         END
```

Table E-1.c. Continued.

```
      SUBROUTINE DATE(I,M,N)
      COMMON
     8/BLK8/MDAY(12)
      ISUM=0
      DO 16 M=1,12
      ISUM=ISUM+MDAY(M)
      IF(I.LE.ISUM) GOTO17
   16 CONTINUE
   17 N=I-ISUM+MDAY(M)
      RETURN
      END
```

```
      SUBROUTINE TEMP(J,TEM)
      COMMON
     9/BLK9/TMON(12)
      DIMENSION MD(12)
      DATA MD/15,45,74,105,135,166,196,227,258,288,319,349/
      IF(J.LE.15) GO TO 40
      IF(J.GT.349) GO TO 41
      DO 42 MM=1,12
      IF(J.LE.MD(MM)) GO TO 43
   42 CONTINUE
   40 TEM=(16+J)/31.*(TMON(1)-TMON(12))+TMON(12)
      GO TO 70
   41 TEM=(J-349)/31.*(TMON(1)-TMON(12))+TMON(12)
      GO TO 70
   43 DIV=FLOAT(MD(MM)-MD(MM-1))
      TEM=(J-MD(MM-1))/DIV*(TMON(MM)-TMON(MM-1))+TMON(MM-1)
      GO TO 70
   70 CONTINUE
      RETURN
      END
```

Table E-1.c. Continued.

```
      SUBROUTINE ES(T,E)
      E=1.3329*EXP(21.07-5336./(T+273.1))
      RETURN
      END


      SUBROUTINE SUBRS(J,XLAT,RS)
      DIMENSION XL30(18),XL40(18),XL50(18),LDAY(18)
      DATA XL30/477.,494.,568.,670.,775.,865.,929.,967.,975.,960.,921.,
     $856.,765.,663.,564.,492.,466.,477./
      DATA XL40/331.,350.,434.,553.,686.,807.,910.,972.,991.,967.,901.,
     $794.,677.,544.,439.,348.,317.,331./
      DATA XL50/188.,205.,289.,419.,575.,732.,867.,958.,989.,954.,859.,
     $725.,568.,414.,286.,204.,176.,188./
      DATA LDAY/0,13,34,56,80,103,126,149,173,196,220,243,266,289,312,
     $334,356,365/
      DO 60 M=1,16
      IF(J.LT.LDAY(M)) GO TO 61
   60 CONTINUE
   61 X=FLOAT(J)
      DM1=FLOAT(LDAY(M))
      DM0=FLOAT(LDAY(M-1))
      PX=(X-DM0)/(DM1-DM0)
      IF(XLAT.GE.40.) GO TO 62
      PY=(XLAT-30.)/10.
      RSB=XL30(M-1)+PX*(XL30(M)-XL30(M-1))
      RST=XL40(M-1)+PX*(XL40(M)-XL40(M-1))
      RS=RSB+PY*(RST-RSB)
      GO TO 63
   62 PY=(XLAT-40.)/10.
      RSB=XL40(M-1)+PX*(XL40(M)-XL40(M-1))
      RST=XL50(M-1)+PX*(XL50(M)-XL50(M-1))
      RS=RSB+PY*(RST-RSB)
   63 RETURN
      END
```

Table E-2.a. Fortran listing of the hydrologic-salinity model for surface runoff.

```
      REAL OC,OO,KO,KC,K1,K2,LOAD,OL,IC,IO,K14,K24
      INTEGER ORDER
      DIMENSION RAIN(5),RUNOFF(5),OC(9,2),OO(9,2),IC(9,2),IO(9,2),KO(9),
     1KC(9),AREA(9),CHL(4),CHD(4),AC(4),BC(4),K1(4),K2(4),CHMASS(4),LOAD
     2(9),LIMIT(4),A(10),B(10),QI(10,2),QO(10,2),NTO(10,10),XMASS(10),RK
     3(10),RX(10),QG(10),CQG(10),QS(10),LOC(9),C(4),S(10,2),CO(10,2),HY(
     42)
      DATA QO/20*3.4/,QI/20*3.4/,OC/18*0.0/,IO/18*0.0/,OO/18*0.0/,IC/18*
     10./,C/4*0.0/,LOAD/9*0.0/,CO/20*0.000/,NTO/100*0/,HY/2*3.4/
C TIME PARAMETERS
      READ(5,10) INLT,NTSTEP,IFLT

C   HW PARAMETERS HYDROGRAPH
      READ(5,20) QB,AHYD,NBGT,NDHYD,HWC
C   STORM PARAMETERS
      READ(5,10) NBGP,NINCR,NDP
      READ(5,40)(RAIN(I),RUNOFF(I),I=1,NINCR)
C  CHANNEL LENGTH AND # OF REACHES
      READ(5,50) UX,DX,NR,SIZE
C  CHANNEL CHARACTERISTICS  (WP=A*QEXPB)
      READ(5,60)(RK(I),RX(I),A(I),B(I),I=1,NR)
C  CHANNEL GROUNDWATER AND SALT AND SEEPAGE
      READ(5,70)(QG(I),CQG(I),QS(I),I=1,NR)
C  # OF SUBBASINS
      READ(5,30)NSUB,ORDER
C  SUBBASIN PT INFLOW,AREA,SLOPE,MICRO DENSITY,MACRO DENSITY
      READ(5,80)(LIMIT(I),K1(I),K2(I),CHL(I),CHD(I),AC(I),BC(I),I=1,ORDE
     1R)
      READ(5,90)(LOC(I),AREA(I),KO(I),KC(I),I=1,NSUB)
   10 FORMAT(3I5)
   20 FORMAT(2F10.5,2I5,F10.5)
   30 FORMAT(2I5)
   40 FORMAT(2F10.5)
   50 FORMAT(2F10.5,I5,F10.5)
   60 FORMAT(4F10.5)
   70 FORMAT(3F10.5)
   80 FORMAT(I5,6F10.5)
   90 FORMAT(I5,3F10.5)
      TOTAL=0.0
      OL=0.
      IFLAG=0
      XL=(DX-UX)/NR*1000.
C       REFLECT INPUT DATA
      WRITE(6,1)

      WRITE(6,2)INLT,NTSTEP,IFLT
      WRITE(6,3)QB,HWC,AHYD,NBGT,NDHYD
      WRITE(6,4)NBGP,NDP
      WRITE(6,5)(RAIN(I),RUNOFF(I),I=1,NINCR)
      WRITE(6,6)UX,DX,NR,NSUB
      WRITE(6,7)
      WRITE(6,8)
      WRITE(6,9)(I,CHL(I),CHD(I),AC(I),BC(I),LIMIT(I),K1(I),K2(I),I=1,OR
     1DER)
      WRITE(6,11)
      WRITE(6,12)(I,LOC(I),AREA(I),KO(I),KC(I),I=1,NSUB)
      WRITE(6,13)
```

Table E-2.a. Continued.

```
      WRITE(6,14)
      WRITE(6,15)(I,A(I),B(I),QG(I),CQG(I),QS(I),RK(I),RX(I),I=1,NR)
    1 FORMAT(1X,"--------------------------------------------------------
     1-- INPUT PARAMETERS --------------------------------------------
     2-----------")
    2 FORMAT("0 TIME PARAMETERS, INITIAL T=",I5,"    ,TIMESTEP=",I5,"    ,
     1FINAL T=",I5)
    3 FORMAT("0 HEADWATER PARAMETERS,  BASE Q=",F8.3,"    ,CONC=",F6.0,"
     1   ,HYDROGRAPH  A=",F8.3,"    ,INITIAL T=",I5,"   ,FINAL T=",I5)
    4 FORMAT("0   PRECIPITATION AND RUNOFF,  INITIAL T=",I5,"    ,FINAL T=
     1",I5,"       RAINFALL       RUNOFF")
    5 FORMAT(66X,F8.3,4X,F8.3)
    6 FORMAT("0 HEADWATER LOCATION=",F4.2,"    ,DOWNSTREAM LOCATION=",F5.
     12,"    ,NUMBER REACHES=",I3,"    ,NUMBER SUBBASINS=",I3)
    7 FORMAT("0",46X,"WETTED PERIMETER              SALT PICKUP RATES")
    8 FORMAT(1X,"STREAM ORDER     MEAN LENGTH  MEAN DENSITY         AC
     1 BC           LIMIT      K1       K2")
    9 FORMAT(6X,I2,11X,F7.1,9X,F5.2,9X,F5.3,2X,F5.3, 6X,I7,4X,F5.3,1X,F5
     1.3)
   11 FORMAT("0   SUBBASIN NUMBER  REACH OF INFLOW    AREA  K-OVERLAND  K-
     1CHANNEL")
   12 FORMAT(9X,I2,15X,I2,8X,F6.3,5X,F6.2,7X,F6.2)
   13 FORMAT("0",14X,"WETTED PERIMETER")
   14 FORMAT(1X,"REACH NUMBER     A          B       GROUNDWATER  CONC. GW
     1SEEPAGE    K-MUSK.     X-MUSK.")
   15 FORMAT(5X,I2,8X,F5.3,3X,F5.3,8X,F7.4,4X,F5.0,4X,F7.4,4X,F6.3,6X,F5
     1.3)
C     END OF REFLECTING INPUT DATA
      WRITE(6,131)
  131 FORMAT("1   OUTFLOW            OUTFLOW CONC.   PRECIPITATION    HEAD
     1WATER       TIME")
      DO 111 IT=INLT,IFLT,NTSTEP
      LIMIT4=LIMIT(4)
      K24=K2(4)
      K14=K1(4)
      R=0.
      P=0.
C  COMPUTE HW
      QH=QB
      IF(IT.LT.NBGT.OR.IT.GT.NDHYD) GO TO 121
      QH=QB+AHYD*(1.-COS(6.283185/(NDHYD-NBGT)*(IT-NBGT)))
  121 CONTINUE
      HY(2)=QH
C  CALL RAIN, SUBBASINS, ETC.
      IF(IT.LT.NBGP.OR.IT.GT.NDP) GO TO 201
      IP=1+(IT-NBGP)/NTSTEP
      P=RAIN(IP)
      R=RUNOFF(IP)
      IF(R.EQ.0) GO TO 201
      IFLAG=IFLAG+1
      CALL OVERLA(IT,NTSTEP,R,OCONC,P)
      GO TO 203
  201 CONTINUE
      DO205M=1,NSUB
      IF(OC(M,2).GT.0) GO TO 203
      IF(OO(M,2).GT.0) GO TO 203
      LOAD(M)=0.
  205 CONTINUE
      GO TO 207
  203 CONTINUE
      CALL OVERLF (OO,IO,NSUB,KO,AREA,NTSTEP,R)
```

```
      CALL CHANFL(OC,IC,NSUB,KC,OO,NTSTEP)
      CALL SALTUP(OO,OC,CHL,CHD,ORDER,NSUB,AC,BC,K1,K2,AREA,LIMIT,CHMASS
     1,OMASS,OCONC,NTSTEP,IT,LOAD,C,OL,NBGP)
  207 CONTINUE
C     CALL HW AND ROUTE FLOW
      CALL ROUTE(QH,QI,QO,NR,RK,RX,NTSTEP,QG,QS,OC,NSUB,LOC)
      CALL CHANSA(IT,NR,NTSTEP,INLT,A,B,XL,QI,QO,K14,K24,LIMIT4,SIZE,C,X
     1MASS,ORDER,NTO)
      NTIME=IT
      Q=QO(NR,2)
      QHW=QH
C     ROUTE SALT
      DO53I=1,NR
      DO 51 K=1,NSUB
      IF(I.NE.LOC(K)) GO TO 51
      XMASS(I)=XMASS(I)+LOAD(K)
   51 CONTINUE
      XTSTEP=NTSTEP
      XMASS(I)=XMASS(I)+CQG(I)*QG(I)*XTSTEP
      DO 53 L=1,2
      AX=RK(I)
      BX=RK(I)*RX(I)
      QOUT=QO(I,L)
      QIN=QI(I,L)
      S(I,L)=AX*QOUT+BX*(QIN-QOUT)
   53 CONTINUE
      IF(QO(NR,2).LE.0) GO TO 81
C  SALT ROUTED DOWNSTREAM
      CALL RTESLT(S,CO,XMASS,QO,QI,NR,NTSTEP,HWC,HY,QS)
      GO TO 82
   81 CO(NR,2)=0.
   82 CONTINUE
      CS=CO(NR,2)
      DO52I=1,NR
      QI(I,1)=QI(I,2)
   52 QO(I,1)=QO(I,2)
      HY(1)=HY(2)
C      END SALT ROUTING
      WRITE(6,141) Q,CS,P,QHW,NTIME
  141 FORMAT(3X,F8.3,13X,F6.0,13X,F3.2,10X,F8.3,7X,I4)
      TOTAL=TOTAL+QO(NR,2)*CO(NR,2)*NTSTEP
  111 CONTINUE
      WRITE(6,311)
  311 FORMAT("1","TOTAL SALT LOAD FROM EVENT,       GRAMS"/"0","STREAM OR
     1DER      CONTRIBUTION")
      WRITE(6,312) (I,C(I),I=1,ORDER)
  312 FORMAT(5X,I2,10X,E10.3)
      WRITE(6,313) OL
  313 FORMAT(1X,"OVERLAND",8X,E10.3)
      DO314N=1,ORDER
  314 OL=OL+C(N)
      WRITE(6,315) OL,TOTAL
  315 FORMAT(11X,"  SUM=",E12.3,"    TOTAL=",E12.3)
      STOP
      END
```

Table E-2.a. Continued.

```
      SUBROUTINE OVERLA (IT,NTSTEP,RUNOFF,OCONC,PRECIP)
      REAL OCONC
C     CALCULATE OVERLAND FLOW OR READ IT IN
      OCONC=366.68+(24.0*(PRECIP)-28.65*RUNOFF)/NTSTEP*60.
      RETURN
      END
```

```
      SUBROUTINE  OVERLF(OO,IO,NSUB,KO,AREA,NTSTEP,RUNOFF)
      REAL OO,IO,KO
      DIMENSION OO(NSUB,2),IO(NSUB,2),KO(NSUB),AREA(NSUB)
      DO1I=1,NSUB
      XTSTEP=NTSTEP
      C=XTSTEP/(KO(I)+XTSTEP/2.)
      IO(I,2)=RUNOFF*AREA(I)*10000.CO/XTSTEP
      OO(I,2)=OO(I,1)+C*(IO(I,1)-OO(I,1))+C*(IO(I,2)-IO(I,1))/2.
      QLIM=.0001
      IF(OO(I,2).LT.QLIM) OO(I,2)=0.
      OO(I,1)=OO(I,2)
      IO(I,1)=IO(I,2)
    1 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CHANFL(OC,IC,NSUB,KC,OO,NTSTEP)
      REAL OC,IC,OO,KC
      DIMENSION OC(NSUB,2),IC(NSUB,2),KC(NSUB),OO(NSUB,2)
      DO1I=1,NSUB
      XTSTEP=NTSTEP
      C=XTSTEP/(KC(I)+XTSTEP/2.)
      IC(I,2)=OO(I,2)
      OC(I,2)=OC(I,1)+C*(IC(I,1)-OC(I,1))+C*(IC(I,2)-IC(I,1))/2.
      QLIM=.0001
      IF(OC(I,2).LT.QLIM) OC(I,2)=0.
      OC(I,1)=OC(I,2)
      IC(I,1)=IC(I,2)
    1 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SALTUP(OO,OC,CHL,CHD,ORDER,NSUB,AC,BC,K1,K2,AREA,LIMIT,
     1CHMASS,OMASS,OCONC,NTSTEP,IT,LOAD,C,OL,NBGP)
      REAL OO,OC,K1,K2,LOAD,OMASS,OCONC,OL
      INTEGER ORDER
      DIMENSION OO(NSUB,2),OC(NSUB,2),CHL(ORDER),CHD(ORDER),AC(ORDER),BC
     1(ORDER),K1(ORDER),K2(ORDER),AREA(NSUB),LIMIT(ORDER),CHMASS(ORDER),
     2LOAD(NSUB),C(ORDER)
      ORDER=ORDER-1
      DO1N=1,NSUB
      AVGOC=OC(N,2)
      OMASS=AVGOC*OCONC*NTSTEP
      LOAD(N)=OMASS
C EST. CHANNEL PICKUP
      OL=OL+OMASS
      DO1I=1,ORDER
      XMIL=CHD(I)*AREA(N)*1000.
      XNUM=XMIL/CHL(I)
      AVGQ=AVGOC/XNUM
      WP=AC(I)*AVGQ**BC(I)
      TNT=IT-NBGP+NTSTEP
      TM1=IT-NBGP
      IF(TNT.GE.LIMIT(I))GO TO 3
      CHMASS(I)=WP*K1(I)*(TNT**.5-TM1**.5)*XNUM*CHL(I)
      GO TO 4
    3 CONTINUE
      CHMASS(I)=WP*XNUM*K2(I)*(TNT**.5-TM1**.5)*CHL(I)
    4 CONTINUE
      LOAD(N)=LOAD(N)+CHMASS(I)
      C(I)=C(I)+CHMASS(I)
    1 CONTINUE
      ORDER=ORDER+1
      RETURN
      END
```

```
      SUBROUTINE RTESLT(S,CO,XMASS,QO,QI,NR,NT,HWC,HY,QS)
       DIMENSION S(NR,2),CO(NR,2),XMASS(NR),QO(NR,2),QI(NR,2),HY(2),QS(N
     1R)
      XT=NT
      DO1I=1,NR
      IM1=I-1
      C=QO(I,1)
      D=QO(I,2)
      H=CO(I,1)
      IF(I.GT.1) GO TO 2
      A=(HY(1)+HY(2))/2.
      CO(I,2)=(H*S(I,1)+A*HWC*XT+QS(I)*HWC*XT+XMASS(I)-H*C*XT/2.)/(S(I,2
     1)+D*XT/2.)
      GO TO 3
    2 B=CO(IM1,1)
      G=CO(IM1,2)
      E=QO(IM1,1)
      F=QO(IM1,2)
      CO(I,2)=(H*S(I,1)+(E*B+G*F)*XT/2.+QS(I)*(B+G)*XT/2.+XMASS(I)-H*C*X
     1T/2.)/(S(I,2)+D*XT/2.)
    3 CONTINUE
      IF(CO(I,2).LT..0001) CO(I,2)=0.
      DELT=S(I,1)/QO(I,1)*2.
      IF(NT.GT.DELT) GO TO 5
    1 CONTINUE
      DO11I=1,NR
   11 CO(I,1)=CO(I,2)
      GO TO 6
    5 CONTINUE
      WRITE(6,10)
   10 FORMAT(1X,"*************** INSTABILITY IN THE CHANNEL ROUTING OF S
     1ALT***************")
    6 CONTINUE
      RETURN
      END
```

```
      SUBROUTINE CHANSA(IT,NR,NTSTEP,INLT,A,B,XL,QI,QO,KO,K1,LIMIT,SIZE,
     1C,XMASS,ORDER,NTO)
      REAL KO,K1,LOAD
      INTEGER ORDER
      DIMENSION A(NR),B(NR),QI(NR,2),QO(NR,2),NTO(NR,10),XMASS(NR),C(ORD
     1ER)
C       CALCULATE MEAN FLOWS
      XTSTEP=NTSTEP
      DO1I=1,NR
      QM=(QI(I,2)+QI(I,1)+QO(I,1)+QO(I,2))/4.
      IF(QM.LE.0) GO TO 73
      AXP2=A(I)*QM**B(I)*XL
      GO TO 74
   73 AXP2=0.
   74 CONTINUE
    4 CONTINUE
C     CALCULATE AREAS
      AR=0.
      NAR=0
    3 NAR=NAR+1
      AR=AR+SIZE
      Z=(AXP2-AR)/SIZE
      NDIFF=(AXP2-AR)/SIZE
      IF(NDIFF)9,8,7
    7 CONTINUE
      GO TO 3
    8 CONTINUE
      GO TO 25
    9 CONTINUE
      GO TO 1000
C     CALCULATE AREAS
   25 CONTINUE
      DO10M=1,NAR
      IF(NTO(I,M).NE.0) GO TO 10
      NTO(I,M)=IT-NTSTEP
   10 CONTINUE
      IF(Z.GE.0) GO TO 26
      Z=Z+1
   26 CONTINUE
      XMASS(I)=0.
      LOAD=0.
      DO27M=1,NAR
      TNT=IT-NTO(I,M)
      XMASS(I)=XMASS(I)+LOAD
      TM1=TNT-NTSTEP
      IF(TNT.GT.LIMIT) GO TO 28
      LOAD=SIZE*KO*(TNT**.5-TM1**.5)
      GO TO 27
   28 LOAD=SIZE*K1*(TNT**.5-TM1**.5)
   27 CONTINUE
      XMASS(I)=XMASS(I)+Z*LOAD
      C(ORDER)=C(ORDER)+XMASS(I)
    1 CONTINUE
      GO TO 1001
 1000 WRITE(6,100)

  100 FORMAT(1X,'ERROR IN CHANSALT')
 1001 CONTINUE
      RETURN
      END
```

Table E-2.a. Continued.

```
      SUBROUTINE ROUTE(QH,QI,QO,NR,RK,RX,NTSTEP,QG,QS,QTRIB,NSUB,LOC)
      DIMENSION QI(NR,2),QO(NR,2),RK(NR),RX(NR),QG(NR),QS(NR),QTRIB(NSUB
     1,2),LOC(NSUB)
      QI(1,2)=QH
      XTSTEP=NTSTEP
      DO10I=1,NR
      QLAT=0.
       DO 20N=1,NSUB
       IF(LOC(N).NE.I) GO TO 20
       QLAT=QLAT+QTRIB(N,2)
20    CONTINUE
       QLAT=QLAT+QS(I)+QG(I)
      QI(I,2)=QI(I,2)+QLAT
      A=RK(I)
      B=RK(I)*RX(I)
      D=(A-B+XTSTEP/2.)
      CO=-(B-XTSTEP/2.)/D
      C1=(B+XTSTEP/2.)/D
      C2=(A-B-XTSTEP/2.)/D
      QO(I,2)=CO*QI(I,2)+C1*QI(I,1)+C2*QO(I,1)
      IP1=I+1
      QLIM=.0001
      IF(QO(I,2).LT.QLIM) QO(I,2)=0.
      IF(I.EQ.NR) GO TO 10
      QI(IP1,2)=QO(I,2)
10    CONTINUE
      RETURN
      END
```

Table E-2.b. Model parameters and descriptions.

Macmonic Term	Description
INLT	Program initialization time, (minutes)
NTSTEP	Timestep, (minutes)
IFLT	Program termination time, (minutes)
QB	Headwater base flow, (m^3/min)
AHYD	One-half amplitúde of sinusoidal generated headwater hydrograph, (m^3/min)
NBGT	Beginning time of headwater hydrograph (minutes)
NDHYD	End time of headwater hydrograph (minutes)
HWC	Headwater concentration, (mg/l)
NBGP	Beginning time of precipitation, (minutes)
NINCR	Number of time increments of precipitation
NDP	End time of precipitation, (minutes)
RAIN	Precipitation during time increment, (cm)
RUNOFF	Surface runoff during time increment, (cm)
UX	Location of headwater, (km)
DX	Location of tailwater, (km)
NR	Number of reaches
SIZE	Area of primary channel wetted perimeter to account salt dissolution (m^2)
RK	Muskinghum routing coefficient, (minutes)
RX	Muskinghum routing coefficient,
A, B	Primary channel wetted perimeter coefficients
QG	Groundwater inflow, (m^3/minutes)
CQG	Concentration groundwater, (mg/l)
QS	Channel seepage flow, ($-m^3$/minutes)
NSUB	Number of lateral subbasins
ORDER	Highest order stream number
LOC	Reach number of lateral subbasin inflow
AREA	Area of subbasins, (km^2)
KO	Linear overland flow routing coefficient, (minutes)
KC	Linear dendritic tributary flow routing coefficient, (minutes)
CHL	Mean channel length with respect to order, (m)
CHD	Mean channel density with respect to order, (km/km^2)
AC, BC	Tributary wetted perimeter coefficients with respect to order
KI	Initial salinity loading coefficient with respect to stream order, gms/m^2-$min^{1/2}$)
LIMIT	Time duration of initial salinity uptake rate, (minutes)
K2	Second salinity loading coefficient with respect to stream order, (gms/m^2-$min^{1/2}$)

Table E-2.c. Input data list and format.

Card Order	Number of Uniform Cards	Format	Parameters	Comments
A	1	3I5	INLT, NTSTEP, IFLT	Time parameter
B	1	2F10.5, 2I5, F10.5	QB, AHYD, NBGT, NDNYD, HWC	Headwater parameter
C	1	3I5	NGBP, NINCR, NDP	Time of precipitation and duration
D	Variable (0-5), f(NINCR)	2F10.5	RAIN, RUNOFF	Precipitation and runoff
E	1	2F10.5, I5, F10.5	UX, DX, NR, SIZE	Primary channel boundaries
F	Variable (1-10), f(NR)	4F10.5	RK, RX, A, B	Primary channel routing and wetted perimeter coefficient
G	Variable (1-10), f(NR)	3F10.5	QG, CQG, QS	Seepage generally < 0
H	1	2I5	NSUB, ORDER	Number of subbasins and highest stream order
I	Variable (1-4), f(ORDER)	I5, 6F10.5	LIMIT, K1, K2, CHL, CHD, AC, BC	Salt loading parameters
J	Variable (1-9), f(NSUB)	I5, 3F10.5	LOC, AREA, KO, KC	Lateral flow routing parameters

Table E-3.a. Fortran listing of the simplified model for predicting salt pickup by overland and microchannel flows.

```
C       MICROCHANNEL HYDROSALINITY MODEL
C


        COMMON/BLK1/XKV(12),BV(12),BT1(12,5),BT2(12,5),XKT1(12,5),
       1XKT2(12,5),DECIS(12,5),XKNS(12),BNS(12),IDUM,A,B,C,H1,H2,H3,
       1H4,H5,TOTPRE,CHANCE,TELIM
       2/BLK2/RUNOFF(5),SS,SMOIS,WP
       3/BLK3/SALT(5),SLOPE,XINT,SALTT,B0,B1,B2,SOFS,SCHS,SCH(5),SOF(5),
       3AREA
       4/BLK4/FC,F0,SI,DKT,SUMRO,TAUSW,RUNS
       5/BLK5/PRECIP(5),TIME
       6/BLK6/XLAT,FICAP,JDAY,CT,AET,IFRF,IFRS,XKC1,XKC2,TX
       7/BLK7/MONT(12)
       8/BLK8/MDAY(12)
       9/BLK9/TMON(12)
       */BLK10/MON
        DATA MDAY/31,28,31,30,31,30,31,31,30,31,30,31/
        DATA MONT/"JAN","FEB","MAR","APR","MAY","JUN","JUL","AUG","SEP",
       *"OCT","NOV","DEC"/
C
C       READ DATA
        READ(5,302)(XKV(J),J=1,12)

        READ(5,302)(BV(J),J=1,12)
        DO 10 I=1,5
        READ(5,302)(BT1(J,I),J=1,12)
        READ(5,302)(BT2(J,I),J=1,12)
        READ(5,302)(XKT1(J,I),J=1,12)
        READ(5,302)(XKT2(J,I),J=1,12)
     10 READ(5,302)(DECIS(J,I),J=1,12)
        READ(5,302)(XKNS(J),J=1,12)
        READ(5,302)(BNS(J),J=1,12)
        READ(5,302)(TMON(J),J=1,12)
        READ(5,300) A,B,C,B0,B1,B2,SLOPE,XINT,CHANL
        READ(5,300) SS,SI,SMOIS,FC,F0,DKT,AREA,TAUSW,XCHCO
        READ(5,300) ELEV,TMAX,TMIN,XLAT,WP,FICAP,XKC1,XKC2,TELIM
        READ(5,301) IDUM,NUMYRS,NSDAY,NEDAY,IFRS,IFRF
        WRITE(6,352)

        WRITE(6,353)
        WRITE(6,*//)A,B,C,B0,B1,B2,SLOPE,XINT,CHANL
        WRITE(6,*//) SS,SI,SMOIS,FC,F0,DKT,AREA,TAUSW,XCHCO
        WRITE(6,*//)ELEV,TMAX,TMIN,XLAT,WP,FICAP,XKC1,XKC2,TELIM
         WRITE(6,*//) IDUM,NUMYRS,NSDAY,NEDAY,IFRS,IFRF
        WRITE(6,363)
    300 FORMAT(7F10.0,2F5.0)
    301 FORMAT(6I10)
    302 FORMAT(12F5.3)
C
```

Table E-3.a. Continued.

```
C      DETERMINE CHARACTERISTIC STORM SHAPE
       H5=A+B+C
       H4=.512*A+.64*B+.8*C
       H3=.216*A+.36*B+.6*C
       H2=.064*A+.16*B+.4*C
       H1=.008*A+.04*B+.2*C
       H5=H5-H4
       H4=H4-H3
       H3=H3-H2
       H2=H2-H1
C
C      DETERMINE CHANNEL LENGTH COEFFICIENT
       SLOPE=SLOPE*(CHANL/100.)**XCHCO
C
C      DETERMINE CONSUMPTIVE USE COEFFICIENTS
       C2=13.
       C1=68.-3.6*ELEV/1000.
       TMIN=(TMIN-32.)/1.8
       TMAX=(TMAX-32.)/1.8
       CALL ES(TMIN,E1)
       CALL ES(TMAX,E2)
       TX=27.5-.25*(E2-E1)-ELEV/1000.
       CH=50./(E2-E1)
       CT=1./(C1+C2*CH)
C
C      BEGIN MODEL
       DO 2000 NYR=1,NUMYRS
       MONO=0
       DO 1999 JDAY=NSDAY,NEDAY
       CALL DATE(JDAY,MON,M)
       IF(MON.EQ.MONO) GO TO 1001
       WRITE(6,354)
       WRITE(6,350)
C      CALCULATE DAILY PROBABILITY OF STORMS IN MONTH MON
       PRI=RANDOM(IDUM)
       ANUMST=BNS(MON)+XKNS(MON)*(-ALOG(-ALOG(PRI)))
       IF(ANUMST.GT.18.)ANUMST=18.
       CHANCE=ANUMST/MDAY(MON)
 1001  CALL RAIN
       CALL CONSUM
       IF(TOTPRE.EQ.0.) GO TO 1997
       CALL HYDRGY
       IF(SUMRO.EQ.0.) GO TO 1996
       CALL SALIN
 1996  WRITE(6,357) MONT(MON),M,TIME,TOTPRE,SUMRO,SCHS,SOFS,SALTT
       IF(SUMRO.EQ.0.) GO TO 1943
       DO 1993 L=1,5
 1993  WRITE(6,382) PRECIP(L),RUNOFF(L),SCH(L),SOF(L),SALT(L)
       WRITE(6,392)
```

Table E-3.a. Continued.

```
1943 CONTINUE
     TOTY=TOTY+TOTPRE
     SOFY=SOFY+SOFS
     SCHY=SCHY+SCHS
     RUNY=RUNY+RUNS
     SALTY=SALTY+SALTT
     TOTM=TOTM+TOTPRE
     SOFM=SOFM+SOFS
     SCHM=SCHM+SCHS
     SALTM=SALTM+SALTT
     RUNM=RUNS+RUNM
     SOFS=0.
     SCHS=0.
     SALTT=0.
1997 MONO=MON
     JD=JDAY+1
     CALL DATE(JD,MONN,MMM)
     IF(MONN.EQ.MON)GO TO 1999
     WRITE(6,360) MONT(MON)
     WRITE(6,374)
     WRITE(6,370)
     WRITE(6,361) TOTM,RUNM,SCHM,SOFM,SALTM
     TOTM=0.
     SOFM=0.
     SCHM=0.
     SALTM=0.
     RUNM=0.
1999 CONTINUE
     WRITE(6,358)
     WRITE(6,368)
     WRITE(6,374)
     WRITE(6,370)
     WRITE(6,361) TOTY,RUNY,SCHY,SOFY,SALTY
     WRITE(6,363)
     TOTY=0.
     SOFY=0.
     SCHY=0.
     RUNY=0.
     SALTY=0.
2000 CONTINUE
 363 FORMAT(1H1)
 360 FORMAT(///,50X,'MONTHLY TOTALS FOR ',A3,//)
 368 FORMAT(///,49X,'**************************',////)
 361 FORMAT(31X,F6.2,8X,F6.2,11X,F6.1,14X,F6.1,14X,F6.1,///////////)
 358 FORMAT(///,55X,'YEARLY TOTALS')
 357 FORMAT(4X,A3,I3,5X,F5.2,12X,F4.2,10X,F4.2,12X,F6.1,15X,F6.1,14X,
    *F6.1)
```

Table E-3.a. Continued.

```
350 FORMAT(15X,'(HRS)',11X,'(INS)',10X,'(INS)',8X,'(LBS/ACRE)',13X,'(L
   *BS/ACRE)',9X,'(LBS/ACRE)',//)
353 FORMAT(25X,'INPUT PARAMETERS',///)
354 FORMAT(5X,'DATE',5X,'DURATION',5X,'PRECIPITATION',5X,'RUNOFF',5X,
   *'MICROCHANNEL SALT',5X,'OVERLAND FLOW SALT',5X,'TOTAL SALT')
352 FORMAT(1H1,////,34X,'HYDRO-SALINITY MODEL OF MICROCHANNELS OF THE
   *PRICE RIVER BASIN',////////)
370 FORMAT(31X,'(INS)',10X,'(INS)',8X,'(LBS/ACRE)',13X,'(LBS/ACRE)',9X
   *,'(LBS/ACRE)',/)
374 FORMAT(27X,'PRECIPITATION',5X,'RUNOFF',5X,'MICROCHANNEL SALT',5X,'
   *OVERLAND FLOW SALT',5X,'TOTAL SALT')
392 FORMAT(/)
382 FORMAT(32X,F6.3,8X,F6.3,11X,F6.1,15X,F6.1,14X,F6.1)
    STOP
    END
```

Table E-3.b. Typical output.

```
HYDRO-SALINITY MODEL OF MICROCHANNELS OF THE PRICE RIVER BASIN



INPUT PARAMETERS


A=3.2  B=4.8  C=0.6  B0=31.0  B1=0.0  B2=0.0  SLOPE=1.75  XINT=0.816  CHANL=120.0

SS=3.0  ST=0.05  SMOIS=1.0  FC=1.7  FO=2.5  DKT=20.0  AREA=0.51  TAUSH=5.0  XCHCO=0.4

ELEV=5500.0  TMAX=90.0  TMIN=57.0  XLAT=40.0  WP=0.5  FICAP=2.0  XKC1=0.58  XKC2=0.89  TELIM=1.5

IDUM=1451777  NUMYRS=4  NSDAY=1  NEDAY=304  IFRS=135  IFRF=275
```

Table E-3.b. Continued.

DATE	DURATION (HRS)	PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)

MONTHLY TOTALS FOR APR

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
0.00	0.00	0.0	0.0	0.0

DATE	DURATION (HRS)	PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
MAY 4	0.38	0.14	0.00	0.0	0.0	0.0
MAY 21	3.03	0.30	0.00	0.0	0.0	0.0

MONTHLY TOTALS FOR MAY

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
0.44	0.00	0.0	0.0	0.0

Table E-3.b. Continued.

DATE	DURATION (HRS)	PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
JUN 1	0.52	0.12	0.00	0.0	0.0	0.0
JUN 4	9.50	1.24	0.00	0.0	0.0	0.0
JUN 7	1.77	0.17	0.00	0.0	0.0	0.0
JUN 10	0.80	0.01	0.00	0.0	0.0	0.0
JUN 16	0.09	0.06	0.00	0.0	0.0	0.0
JUN 20	0.10	0.02	0.00	0.0	0.0	0.0
JUN 22	0.09	0.05	0.00	0.0	0.0	0.0
JUN 29	0.91	0.20	0.00	0.0	0.0	0.0
JUN 30	0.41	0.14	0.00	0.0	0.0	0.0

MONTHLY TOTALS FOR JUN

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
2.01	0.00	0.0	0.0	0.0

DATE	DURATION (HRS)	PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
JUL 5	0.07	0.05	0.00	0.0	0.0	0.0
JUL 9	1.52	0.09	0.00	0.0	0.0	0.0
JUL 17	1.17	0.03	0.00	0.0	0.0	0.0
JUL 18	0.42	0.15	0.00	0.0	0.0	0.0
JUL 21	0.53	0.11	0.00	0.0	0.0	0.0

Table E-3.b. Continued.

MONTHLY TOTALS FOR JUL

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
0.43	0.00	0.0	0.0	0.0

DATE	DURATION (HRS)	PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
AUG 1	4.95	0.70	0.00	0.0	0.0	0.0
AUG 2	4.61	0.21	0.00	0.0	0.0	0.0
AUG 5	0.72	0.37	0.00	0.0	0.0	0.0
AUG 17	0.10	0.10	0.00	0.0	0.0	0.0

MONTHLY TOTALS FOR AUG

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
1.38	0.00	0.0	0.0	0.0

Table E-3.b. Continued.

DATE	DURATION (HRS)	PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
SEP 13	1.66	0.06	0.00	0.0	0.0	0.0

MONTHLY TOTALS FOR SEP

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
0.06	0.00	0.0	0.0	0.0

DATE	DURATION (HRS)	PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
OCT 2	1.87	0.27	0.00	0.0	0.0	0.0
OCT 4	2.56	0.24	0.00	0.0	0.0	0.0
OCT 25	0.76	0.08	0.00	0.0	0.0	0.0

MONTHLY TOTALS FOR OCT

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
0.59	0.00	0.0	0.0	0.0

Table E-3.b. Continued.

YEARLY TOTALS

****

PRECIPITATION (INS)	RUNOFF (INS)	MICROCHANNEL SALT (LBS/ACRE)	OVERLAND FLOW SALT (LBS/ACRE)	TOTAL SALT (LBS/ACRE)
4.01	0.00	0.0	0.0	0.0

Table E-4.a. The correlation procedures used to estimate flows at Heiner.

```
#ET=4:55.8 PT=1.0 IO=1.1
E$STATPAC/MREFDEL
E$STATPAC/MREGT
#RUNNING 4575
ENTER (YES) TO RESTRICT OUTPUT TO THE AOV

#?
NO
ENTER: #X'S, #Y'S
2,1
ENTER (YES) FOR AN INTERCEPT
YES
ENTER DEVICE CODE FOR DATA INPUT, 5,10 OR 11
5
ENTER NUMBER OF DATA TRANSFORMATIONS YOU WANT TO MAKE, 0 TO 20
0
ENTER (YES) TO TAKE LOG OF Y'S
NO
ENTER EACH RECORD, X'S FOLLOWED BY Y'S.
ENTER  ?END  TO END DATA INPUT
464,11,1150
976,40,1460
705,38,100DEL
705,38,1070
865,128,1850
565,1,922
721.1DEL
721,0,756
966,131,DEL
966,14,1010
?END

#


MEANS AND S.D.
    1  .75171429E+03  .19571383E+03
    2  .33142857E+02  .44827181E+02
    3  .11740000E+04  .36862085E+03
ENTER (YES) FOR UNCORRECTED SS SP

#?
NO


CORRECTED SS AND SP
    1  .22982343E+06  .21345286E+05  .17723800E+06
    2  .12056857E+05  .91204000E+05
    3  .81528800E+06

CORRELATION ELEMENTS
  1 1.00000 0.40550 0.40945
  2 1.00000 0.91990
  3 1.00000

INVERSE MATRIX
    1  .52074100E-05 -.92191235E-05
    2  .99261757E-04

REGRESSION ANALYSIS OF VARIABLE  3
```

Table E-4.a. Continued.

```
SOURCE      DF  MEAN SQUARES                   COEFF      STND C       S(B)
 TOTAL       6  .13588133E+06 B(   0)=  .866372E+03              .291278E+03
 B(   1)     1  .12953343E+04 B(   1)=  .821300E-01  0.044      .401914E+00
 B(   2)     1  .55452273E+06 B(   2)=  .741909E+01  0.902      .175474E+01
 MODEL       2  .34560363E+06 R SQR  =  .847807E+00
 ERROR       4  .31020183E+05
ENTER (YES) FOR PREDICTED VALUES
YES

ENTER (YES) FOR STANDARD DEVIATIONS
NO


  NO.    OBSERVED     PREDICTED     DEVIATION
    1    1150.0       986.09        163.91
    2    1460.0       1243.3        216.71
    3    1070.0       1206.2       -136.20
    4    1850.0       1887.1       -37.058
    5    922.00       920.19        1.8056
    6    756.00       925.59       -169.59
    7    1010.0       1049.6       -39.577
DURBIN-WATSON=  1.491
ENTER (YES) FOR RIDGE REGRESSION
NO
```

Table E-4.b. Output from the calibration run.

```
VAR OCT NOV DEC JAN FEB MAR     APR MAY JUN JUL AUG SEP ANN
  1 PHR TEMP    2    PRECIP    3 SNOW MLT    4 SNOW STR    5    PHR ET    6 CROP PET
  7 CROP AET    8    SM STR    9 RIVER IN   10  TRIB IN   11    UNG IN   12 PHR RPSM
 13  URB SRF   14   PUMP IN   15 RIVER GW   16  PHR SUP   17   WTR AVL   18  M+I DIV
 19  M+I RET   20   WTR AVL   21 CNL DIV    22 CNL SEEP   23    CNL GW   24 SEEP RTN
 25    SPILL   26 FARM DEL    27 TAIL WTR   28  TAL EVP   29   TOT SPL   30 CROP AET
 31 SM STR     32        DP   33 ROUT DP    34 REDIV RF   35 RDP NDIV   36    GW IN
 37 URBGW IN   38    PHR GW   39  ROUT GW   40  EFFL GW   41 CH GWSTR   42   GW OUT
 43 CHNL EXP   44 SUR RNOF    45 COMP OUT   46 GAGE OUT   47      DIFF  48   SM MG/L
 49   SALTIN   50    NAT PU   51   AGR PU   52  RES REL   53   RES STR  54  URB SUR
 55  PUMP IN   56 RIVER GW    57 SALT AVL   58  M+I DIV   59   M+I RET  60 SALT AVL
 61  CNL DIV   62 CNL SEEP    63   CNL GW   64 SEEP RET   65     SPILL  66 FARM DEL
 67  TAILWTR   68  APPLIED    69   SMSTRG   70 PCP RTZN   71    PCP DP  72   DPSALT
 73  ROUT DP   74  PPM ARF    75  ARF DIV   76  ARF RTN   77     GW IN  78 URBGW IN
 79  GW EFL    80  GW CONC    81   GW  OUT  82 CH GWSTR   83    EXPORT  84    SUR RO
 85 COMP OUT   86 GAGE OUT    87     DIFF   88 COMP TDS   89 GAGE TDS   90      DIFF
 91 PPT RES    92 RES EVP     93 PPT-EVP    94 SUR INF    95 AVE AREA   96 REQ REL
 97 ACT REL    98 CAN DIV     99 RES EXP   100 RES REL   101 RES STOR  102 DEL STOR
103 CONC      104 CONC       105           106           107           108
109           110
KCMI        .100  .100  .100  .100  .100  .100  .100  .100  .100  .100  .100  .100
 PDL        .077  .067  .075  .067  .067  .083  .089  .100  .100  .102  .095  .083
1ALFALF     .920  .800  .680  .680  .800  .880 1.000 1.080 1.120 1.100 1.080 1.000
2PASTUR     .790  .670  .540  .490  .580  .730  .850  .900  .920  .920  .910  .860
3GRAIN      .250  .250  .250  .250  .250  .250  .260  .500 1.540 1.120  .250  .250
4CORN       .400  .400  .100  .100  .100  .100  .100  .180  .640  .980 1.080 1.020
5POTATO     .250  .250  .250  .250  .250  .250  .250  .250  .380  .900 1.320 1.320
6ORCHAR     .300  .100  .160  .170  .250  .390  .630  .860  .960  .950  .810  .540
7SUGAR      .600  .400  .400  .400  .400  .400  .420  .450  .660 1.100 1.250 1.040
8OTHER      .630  .540  .430  .390  .460  .582  .680  .720  .740  .740  .730  .600
9PHREAT    1.250 1.000  .750  .650  .800 1.150 1.350 1.400 1.400 1.400 1.400 1.350
10OPENWA   1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.000 1.200 1.000

SUB 7 1973 TO 1975  PRICE RIVER FROM HEINER TO WOODSIDE
LAND AREAS
      CROP LAND          PHR LAND            URB LAND           UND LAND        TOTAL LAND
          25545.            1770.               8000.                0.            36315.
INCH TO AC-FT CONVERSION FACTORS
     2212.083007        147.500000          666.666625          .000000       3026.250000
CROP AND PHREATOPHYTE ACRES
  1      0.     2   9200.     3   4600.     4  11250.     5      25.     6     100.
  7   1120.     8    250.     9    370.    10   1400.
PROP CROP AND PHR
  1   .000000  2   .346581  3   .173290  4   .423808  5   .000941  6   .003767
  7   .042192  8   .009417
  9   .209039 10   .790960
WEIGHTED CROP AND PHR COEFFICIENTS
 .519  .457  .294  .275  .309  .362  .408  .504  .895  .986  .880  .827
1.052 1.000  .947  .926  .956 1.031 1.073 1.083 1.083 1.083 1.083 1.073
```

Table E-4.b. Continued.

HYDROLOGIC DATA

3 3 1 1 1 1 1 1 0 1 0 0 0 0 0 1 1 1 1 1 0 1 0 0

1HIAWATHA1973	41.70	29.40	20.00	18.50	24.40	31.70
	39.00	48.40	60.00	65.00	65.00	55.00
	41.50					
1HIAWATHA1974	43.00	35.00	27.00	20.00	25.00	37.20
	39.90	55.70	61.00	67.00	67.50	59.10
	44.78					
1HIAWATHA1975	48.50	33.40	23.10	21.00	24.70	31.00
	35.40	47.40	57.20	68.70	66.10	59.20
	42.97					
1SUNNYSID1973	45.90	29.00	20.00	19.00	24.00	32.00
	39.00	52.60	60.00	65.00	67.20	55.00
	42.39					
1SUNNYSID1974	49.00	34.00	27.00	16.00	21.00	38.00
	40.50	55.20	61.00	67.00	66.50	58.70
	44.49					
1SUNNYSID1975	50.30	34.70	22.90	21.00	24.20	31.20
	35.80	46.40	56.50	69.20	65.50	59.40
	43.09					
1PRICE WA1973	52.30	35.00	22.00	16.90	26.80	37.10
	45.10	57.90	65.10	71.90	72.30	63.90
	47.19					
1PRICE WA1974	55.70	38.40	29.20	18.60	23.20	42.10
	45.00	61.60	74.20	78.00	73.60	68.40
	50.66					
1PRICE WA1975	55.70	38.40	31.30	25.00	31.60	41.30
	43.70	53.60	59.90	72.30	71.00	63.90
	48.97					
2HIAWATHA1973	4.50	1.73	1.30	.24	1.22	1.86
	1.11	.41	.55	2.95	1.05	.37
	17.29					
2HIAWATHA1974	.19	.45	.61	.84	.13	.15
	.59	.00	.00	1.59	.28	.33
	5.16					
2HIAWATHA1975	3.35	.89	.49	1.00	.88	1.55
	.58	1.01	1.86	.62	.77	.67
	13.67					
2SUNNYSID1973	4.31	1.34	1.17	.62	.41	1.51
	.84	1.15	1.40	1.97	1.17	.21
	16.10					
2SUNNYSID1974	.56	.42	.36	.81	.10	.07
	.56	.00	.04	2.12	.35	.21
	5.60					
2SUNNYSID1975	4.08	.22	.53	.76	.59	2.22
	.61	1.84	1.44	3.05	.06	.32
	15.72					
2PRICE WA1973	4.34	.83	.68	.58	.97	1.03
	.49	.28	1.26	1.72	1.20	.34
	13.72					
2PRICE WA1974	.26	.25	.50	.70	.03	.00
	.06	.00	.00	.34	.06	.16
	2.36					
2PRICE WA1975	3.87	.36	.25	.76	.69	1.11
	.00	.74	.92	1.54	.06	1.26
	11.56					
3HEINER 1973	2400.00	789.99	1300.00	679.99	839.99	1550.00
	9800.00	43300.00	12800.00	10100.00	13500.00	5700.00
	102959.98					
3HEINER 1974	2879.99	1500.00	1700.00	1029.99	939.99	1759.99
	4979.99	17400.00	13000.00	10100.00	11000.00	3739.99
	70029.96					
3HEINER 1975	1250.00	1139.99	950.00	679.99	850.00	2029.99

Table E-4.b. Continued.

		8350.00	10300.00	27300.00	17300.00	13100.00	7800.00
		88359.98					
16 TDSHE	1973	479.99	600.00	369.99	519.99	519.99	489.99
		359.99	400.00	539.99	500.00	509.99	579.99
		469.16					
16 TDSHE	1974	559.99	559.99	400.00	609.99	609.99	600.00
		559.99	539.99	529.99	519.99	529.99	609.99
		552.49					
16 TDSHE	1975	700.00	579.99	500.00	550.00	450.00	450.00
		750.00	550.00	350.00	450.00	450.00	479.99
		521.66					
4IMPORT	1973	650.00	300.00	360.00	240.00	220.00	250.00
		750.00	5000.00	7000.00	6000.00	5000.00	3500.00
		29270.00					
4IMPORT	1974	1500.00	700.00	300.00	200.00	200.00	500.00
		2500.00	7000.00	5750.00	4750.00	4000.00	2400.00
		28800.00					
4IMPORT	1975	850.00	450.00	300.00	200.00	250.00	500.00
		1000.00	5400.00	6300.00	6750.00	6000.00	4000.00
		32000.00					
17 IMTDS	1973	700.00	700.00	700.00	700.00	700.00	700.00
		700.00	700.00	700.00	700.00	700.00	700.00
		699.99					
17 IMTDS	1974	700.00	700.00	700.00	700.00	700.00	700.00
		700.00	700.00	700.00	700.00	700.00	700.00
		699.99					
17 IMTDS	1975	700.00	700.00	700.00	700.00	700.00	700.00
		700.00	700.00	700.00	700.00	700.00	700.00
		699.99					
5GORCP	1973	52.00	.00	.00	.00	.00	.00
		20.00	250.00	621.99	333.99	203.99	230.00
		1711.99					
5GORCP	1974	216.99	13.00	.00	.00	.00	32.00
		191.99	280.00	210.00	116.99	115.99	95.00
		1271.99					
5GORCP	1975	43.00	.00	.00	.00	.00	.00
		70.00	371.99	440.99	196.99	107.99	82.00
		1312.99					
18 TDSCO	1973	2799.99	3199.99	3799.99	3799.99	5099.99	2799.99
		2299.99	2299.99	2299.99	2399.99	2099.99	1500.00
		2866.66					
18 TDSCO	1974	2199.99	1899.99	3500.00	3799.99	5199.99	2599.99
		2599.99	3099.99	2199.99	2099.99	2199.99	3599.99
		2916.66					
18 TDSCO	1975	2799.99	3000.00	3500.00	4000.00	5199.99	2000.00
		2599.99	3000.00	2299.99	2000.00	1599.99	3000.00
		2924.99					
6 CANAL	1973	1559.99	750.00	929.99	619.99	579.99	729.99
		2000.00	13129.99	18200.99	15529.99	12939.99	9000.00
		76079.96					
6 CANAL	1974	4429.99	1919.99	819.99	619.99	559.99	1450.00
		6409.99	18559.99	14750.00	12279.99	10419.99	6179.99
		78399.95					
6 CANAL	1975	2239.99	1229.99	769.99	619.99	739.99	1359.99
		2739.99	13869.99	16179.99	17339.99	15719.99	10689.99
		83499.95					
7 GW IN	1973	330.00	330.00	330.00	330.00	330.00	330.00
		330.00	330.00	330.00	330.00	330.00	330.00
		3960.00					
7 GW IN	1974	330.00	330.00	330.00	330.00	330.00	330.00
		330.00	330.00	330.00	330.00	330.00	330.00
		3960.00					
7 GW IN	1975	330.00	330.00	330.00	330.00	330.00	330.00

Table E-4.b. Continued.

		330.00	330.00	330.00	330.00	330.00	330.00
		3960.00					
19 TDSGW	1973	309.99	309.99	309.99	309.99	309.99	309.99
		309.99	309.99	309.99	309.99	309.99	309.99
		309.99					
19 TDSGW	1974	309.99	309.99	309.99	309.99	309.99	309.99
		309.99	309.99	309.99	309.99	309.99	309.99
		309.99					
19 TDSGW	1975	309.99	309.99	309.99	309.99	309.99	309.99
		309.99	309.99	309.99	309.99	309.99	309.99
		309.99					
8 WOOD	1973	22450.00	4029.99	2989.99	2459.99	2800.00	10689.99
		15450.00	45209.99	13469.99	10119.99	5750.00	3589.99
		139009.90					
8 WOOD	1974	4300.00	3219.99	3800.00	3729.99	3369.99	3729.99
		3029.99	4600.00	3619.99	3600.00	1159.99	959.99
		39119.96					
8 WOOD	1975	2950.00	2050.00	1289.99	1319.99	1639.99	2900.00
		3759.99	5450.00	14769.99	7300.00	2409.99	3379.99
		49219.96					
20 TDSWD	1973	2199.99	2799.99	3399.99	2500.00	2399.99	2099.99
		1599.99	799.99	1500.00	2099.99	2000.00	2299.99
		2141.66					
20 TDSWD	1974	2500.00	2599.99	2599.99	2500.00	2299.99	2399.99
		2199.99	1899.99	2199.99	2199.99	2599.99	3000.00
		2415.66					
20 TDSWD	1975	2500.00	2699.99	3500.00	2500.00	2399.99	2299.99
		2699.99	2399.99	899.99	3000.00	1599.99	2000.00
		2374.99					
1073 M+I	1973	730.00	635.00	635.00	635.00	635.00	635.00
		635.00	635.00	945.00	945.00	945.00	730.00
		8740.00					
1074 M+I	1974	775.00	670.00	670.00	670.00	670.00	670.00
		670.00	670.00	1000.00	1000.00	1000.00	775.00
		9240.00					
1075 M+I	1975	850.00	740.00	740.00	740.00	740.00	740.00
		740.00	740.00	1100.00	1100.00	1100.00	850.00
		10180.00					
2273 TDSMI	1973	309.99	309.99	309.99	309.99	309.99	309.99
		309.99	309.99	309.99	309.99	309.99	309.99
		309.99					
2274 TDSMI	1974	309.99	309.99	309.99	309.99	309.99	309.99
		309.99	309.99	309.99	309.99	309.99	309.99
		309.99					
2275 TDSMI	1975	309.99	309.99	309.99	309.99	309.99	309.99
		309.99	309.99	309.99	309.99	309.99	309.99
		309.99					

Table E-4.b. Continued.

VAR(1) 1973	46.63	31.13	20.66	18.13	25.06	33.60
	41.03	52.96	61.59	67.30	68.16	57.96
	43.69					
VAR(1) 1974	49.23	35.80	27.73	18.20	23.06	39.10
	41.80	57.50	65.40	70.66	69.19	62.06
	46.64					
VAR(1) 1975	51.53	35.50	25.76	22.33	26.83	34.50
	39.30	49.13	57.86	70.06	67.53	60.83
	45.01					
VAR(2) 1973	4.38	1.30	1.05	.48	.56	1.46
	.81	.61	1.07	2.21	1.14	.38
	15.70					
VAR(2) 1974	.33	.37	.49	.78	.08	.07
	.40	.00	.01	1.35	.23	.23
	4.37					
VAR(2) 1975	3.76	.49	.42	.84	.72	1.62
	.39	1.19	1.40	1.73	.29	.75
	13.65					
VAR(3) 1973	2400.00	789.99	1300.00	879.99	839.99	1550.00
	9602.00	43300.00	12800.00	10100.00	13570.00	5700.00
	102959.98					
VAR(3) 1974	2879.99	1500.00	1700.00	1029.99	939.99	1759.99
	4979.99	17400.00	13000.00	10100.00	11000.00	3739.99
	70029.96					
VAR(3) 1975	1250.00	1139.99	950.00	679.99	850.00	2029.99
	5959.99	10300.00	27900.00	17300.00	13100.00	7800.00
	88359.98					
VAR(4) 1973	654.00	320.00	360.00	240.00	220.00	250.00
	750.00	5000.00	7000.00	6000.00	5000.00	3500.00
	29270.00					
VAR(4) 1974	1500.00	700.00	300.00	200.00	200.00	500.00
	2500.00	7000.00	5750.00	4750.00	4000.00	2400.00
	29800.00					
VAR(4) 1975	850.00	450.00	300.00	200.00	250.00	500.00
	1000.00	5400.00	6300.00	6750.00	6000.00	4000.00
	32000.00					
VAR(5) 1973	52.00	.00	.00	.00	.00	.00
	20.00	250.00	621.99	333.99	203.99	230.00
	1711.99					
VAR(5) 1974	215.99	13.00	.00	.00	.00	32.00
	191.99	280.00	210.00	116.99	115.99	95.00
	1271.99					
VAR(5) 1975	43.00	.00	.00	.00	.00	.00
	70.00	371.99	440.99	196.99	107.99	82.00
	1312.99					
VAR(6) 1973	1659.99	750.00	929.99	619.99	579.99	729.99
	2003.00	13129.99	18209.99	15529.99	12939.99	9000.00
	76079.95					
VAR(6) 1974	4429.99	1919.99	819.99	619.99	559.99	1450.00
	6409.99	18559.99	14750.00	12279.99	10419.99	6179.99
	78399.95					
VAR(6) 1975	2239.99	1220.99	769.99	619.99	739.99	1359.99
	2739.99	13869.99	16179.99	17339.99	15719.99	10689.99
	83499.95					
VAR(7) 1973	330.00	330.00	330.00	330.00	330.00	330.00
	330.00	330.00	330.00	330.00	330.00	330.00
	3960.00					
VAR(7) 1974	330.00	330.00	330.00	330.00	330.00	330.00
	330.00	330.00	330.00	330.00	330.00	330.00
	3960.00					
VAR(7) 1975	330.00	330.00	330.00	330.00	330.00	330.00
	330.00	330.00	330.00	330.00	330.00	330.00

Table E-4.b. Continued.

	3960.00					
VAR(8) 1973	22450.00	4029.99	2989.99	2459.99	2800.00	10689.99
	15450.00	45209.99	13469.99	10119.99	5750.00	3589.99
	139009.90					
VAR(8) 1974	4300.00	3219.99	3800.00	3729.99	3369.99	3729.99
	3029.99	4600.00	3619.99	3600.00	1159.99	959.99
	39119.96					
VAR(8) 1975	2950.00	2050.00	1289.99	1319.99	1639.99	2000.00
	3759.99	5450.00	14769.99	7300.00	2409.99	3379.99
	49219.96					
VAR(10) 1973	730.00	635.00	635.00	635.00	635.00	635.00
	635.00	635.00	945.00	945.00	945.00	730.00
	8740.00					
VAR(10) 1974	775.00	670.00	670.00	670.00	670.00	670.00
	670.00	670.00	1000.00	1000.00	1000.00	775.00
	9240.00					
VAR(10) 1975	850.00	740.00	740.00	740.00	740.00	740.00
	740.00	740.00	1100.00	1100.00	1100.00	850.00
	10180.00					
VAR(16) 1973	1565.64	644.19	653.71	621.90	593.63	1032.20
	4794.77	23539.00	9393.85	6863.27	9357.16	4493.06
	63552.42					
VAR(16) 1974	2191.89	1141.61	924.16	853.90	779.28	1435.17
	3790.15	12769.77	9363.95	7137.80	7923.34	3100.56
	51411.62					
VAR(16) 1975	1189.18	898.61	645.55	508.29	519.84	1241.50
	5157.65	7699.10	13271.26	10580.32	8011.68	5088.33
	54811.33					
VAR(17) 1973	618.37	285.40	342.48	228.32	209.29	237.83
	713.50	4756.72	6659.41	5708.07	4756.72	3329.70
	27845.87					
VAR(17) 1974	1427.01	665.94	285.40	190.26	190.26	475.67
	2378.36	6659.41	5470.23	4518.89	3805.38	2283.22
	28350.08					
VAR(17) 1975	808.64	428.10	285.40	190.26	237.83	475.67
	951.34	5137.26	5993.47	6421.58	5708.07	3805.38
	30443.64					
VAR(18) 1973	197.87	.00	.00	.00	.00	.00
	62.51	781.46	1944.27	1089.42	582.22	468.87
	5126.66					
VAR(18) 1974	648.81	33.56	.00	.00	.00	113.07
	678.44	1179.66	627.88	333.92	346.83	464.80
	4427.01					
VAR(18) 1975	163.63	.00	.00	.00	.00	.00
	256.86	1516.71	1378.49	535.47	234.84	334.32
	4420.35					
VAR(19) 1973	139.03	139.03	139.03	139.03	139.03	139.03
	139.03	139.03	139.03	139.03	139.03	139.03
	1668.38					
VAR(19) 1974	139.03	139.03	139.03	139.03	139.03	139.03
	139.03	139.03	139.03	139.03	139.03	139.03
	1668.38					
VAR(19) 1975	139.03	139.03	139.03	139.03	139.03	139.03
	139.03	139.03	139.03	139.03	139.03	139.03
	1668.38					
VAR(20) 1973	67124.20	15335.68	13816.24	8358.24	9132.91	30509.63
	33596.07	49154.64	27459.90	28882.83	15629.24	11221.79
	310221.18					
VAR(20) 1974	14609.94	11378.00	13427.55	12673.27	10534.10	12166.34
	9059.52	11878.22	10823.58	10763.79	4098.93	3914.10
	125327.43					
VAR(20) 1975	10823.10	7522.42	6136.17	4484.91	5349.27	9864.96
	13797.22	17776.56	18066.04	29763.51	5240.55	9187.27

Table E-4.b. Continued.

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                136411.96
VAR(22) 1973       307.55      267.53      267.53      267.53      267.53      267.53
                   267.53      267.53      398.13      398.13      398.13      307.55
                  3682.24
VAR(22) 1974       326.51      282.27      282.27      282.27      282.27      282.27
                   282.27      282.27      421.31      421.31      421.31      326.51
                  3892.98
VAR(22) 1975       358.11      311.76      311.76      311.76      311.76      311.76
                   311.76      311.76      463.44      463.44      463.44      358.11
                  4288.93
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PRICE RIVER FROM HEINER TO WOODSIDE
110 -1 -2  0  0 75  .100E+01  .100E-05  .100E-05  .100E-05
  IDTM      1 1 1 1 1 1 1 1 1 1 1 1
  SOILMOI .000 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000 .000
  OBJ COE1.0001.0001.0001.0001.0001.0001.0001.0001.0001.0001.0001.000 .0001.000
PAR    1         2         3         4         5         6         7         8         9        10
     .000      .300    27.000    33.000     3.0002000.0001892.099     1.400519400.0     3.600
    5.500     2.400    18.000     7.000     1.000     1.000      .200      .010      .790      .850
 1000.000      .300      .200      .000      .000      .0001000.000      .100      .400     1.050
     .950     1.300     1.000     1.000     1.000     1.200      .000      .200      .500      .500
     .500      .000      .100      .000      .000      .000      .000      .000     4.000     1.400
    1.400     1.300     2.000     2.000     5.000      .000      .000      .000      .000      .000
     .000      .000      .000      .000      .000      .000      .000      .000      .000      .000
     .000      .000      .000     2.500      .010      .0053000.000000.000      .6004000.000
 3500.000      .000     1.500      .020   000.000      .000     1.720      .000      .200      .000
 5000.000     7.000      .030     1.000      .500     1.300      .000      .000   000.0002350.000
 2100.0002069.0003000.0004900.000   500.000      .000      .000      .000      .000      .000
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Table E-4.b. Continued.

PRICE RIVER FROM HEINER TO WOODSIDE YEAR 1973
WATER

VAR		OCT	NOV	DEC	JAN	FEB	MAR
1	FHR TEMP	48.964	32.689	21.699	19.039	26.319	35.279
2	PRECIP	4.164	1.235	.997	.456	.823	1.393
3	SNOW MLT	.000	1.010	.000	.000	.000	2.292
4	SNOW STR	.000	.224	1.221	1.677	2.500	.208
5	PHR ET	2.128	.659	.453	.357	.508	.909
6	CROP PET	1.260	.370	.173	.128	.196	.383
7	CROP AET	1.260	.370	.173	.128	.196	.383
8	SM STR	7.466	7.127	6.298	5.583	4.930	7.216
9	RIVER IN	2420.	790.	1300.	880.	840.	1550.
10	TRIB IN	652.	300.	360.	240.	220.	250.
11	UNG IN	16330.	1821.	0.	0.	0.	4384.
12	PHR RPSN	514.	149.	0.	0.	0.	543.
13	URB SRF	694.	168.	0.	0.	0.	614.
14	PUMP IN	0.	0.	0.	0.	0.	0.
15	RIVER GW	0.	0.	0.	0.	0.	0.
16	PHR SUR	0.	0.	54.	42.	60.	0.
17	WTR AVL	20469.	3175.	1655.	1112.	1031.	7247.
18	M+I DIV	730.	635.	635.	635.	635.	635.
19	M+I RET	657.	571.	571.	571.	571.	571.
20	WTR AVL	20396.	3111.	1592.	1048.	968.	7184.
21	CNL DIV	2158.	975.	1209.	806.	754.	949.
22	CNL SEEP	453.	204.	253.	169.	158.	199.
23	CNL GW	378.	171.	201.	137.	127.	158.
24	SEEP RTN	94.	42.	50.	34.	31.	39.
25	SPILL	21.	9.	12.	8.	7.	9.
26	FARM DEL	1583.	760.	943.	628.	588.	740.
27	TAIL WTR	252.	114.	141.	94.	88.	111.
28	TAL EVP	0.	0.	0.	0.	0.	0.
29	TOT SPL	10642.	2882.	801.	534.	499.	8782.
30	CROP AET	2788.	818.	382.	283.	435.	848.
31	SM STR	16520.	15765.	13932.	12351.	10907.	15964.
32	DP	3499.	2818.	2251.	1831.	1508.	2876.
33	ROUT DP	6406.	4314.	3544.	3121.	3945.	4247.
34	REDIV RF	0.	0.	0.	0.	0.	0.
35	RDP NDIV	6406.	4314.	3544.	3121.	3945.	4247.
36	GW IN	330.	330.	330.	330.	330.	330.
37	URBGW IN	694.	168.	0.	0.	0.	614.
38	PHR GW	0.	0.	13.	10.	15.	0.
39	ROUT GW	7808.	4984.	4363.	3579.	4387.	5350.
40	EFFL GW	4685.	2990.	2437.	2147.	2632.	3210.
41	CH GWSTR	0.	-0.	-.	-.	.	.
42	GW OUT	3123.	1993.	1625.	1431.	1754.	2140.
43	CHNL EXP	0.	0.	0.	0.	0.	0.
44	SUR RNOF	23198.	5251.	2974.	2492.	2942.	9566.
45	COMP OUT	23198.	5251.	2974.	2492.	2942.	9566.
46	GAGE OUT	22450.	4030.	2990.	2460.	2800.	10689.
47	DIFF	746.	1221.	-15.	32.	142.	-1123.

Table E-4.b. Continued.

	APR	MAY	JUN	JUL	AUG	SEP	ANN
1	43.084	55.614	64.704	70.664	71.574	60.864	45.002
2	.772	.582	1.016	2.102	1.083	.291	14.918
3	.206	.001	.000	.000	.000	.000	3.511
4	.001	.000	.000	.000	.000	.002	.000
5	1.785	3.913	5.709	7.109	6.838	4.049	34.433
6	.815	2.184	5.663	7.763	6.666	3.746	29.353
7	.815	2.184	5.663	7.763	6.666	3.530	29.130
8	6.844	8.331	7.595	5.005	2.717	1.717	5.903
9	9800.	43300.	12800.	10100.	13500.	5700.	102959.
10	750.	5000.	7000.	6300.	5000.	3500.	29270.
11	273.	750.	1866.	2331.	612.	690.	29060.
12	144.	86.	149.	310.	159.	42.	2200.
13	163.	97.	169.	350.	100.	48.	2486.
14	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.
16	95.	392.	553.	590.	679.	443.	2912.
17	10998.	49449.	22201.	18989.	19323.	9919.	165574.
18	635.	635.	945.	945.	945.	730.	8740.
19	571.	571.	850.	850.	850.	657.	7866.
20	10935.	49386.	22106.	18894.	19228.	9846.	164780.
21	2500.	17068.	22106.	18894.	16821.	9846.	94190.
22	546.	3584.	4642.	3967.	3532.	2067.	19780.
23	426.	2780.	3680.	3192.	2839.	1696.	15790.
24	106.	695.	920.	798.	709.	424.	3947.
25	26.	170.	221.	188.	168.	98.	941.
26	2028.	13313.	17243.	14738.	13121.	7680.	73468.
27	304.	1997.	2586.	2210.	1968.	1152.	11020.
28	0.	0.	0.	0.	0.	0.	0.
29	3890.	12639.	16905.	17178.	13548.	7172.	95448.
30	1804.	4833.	12527.	17174.	14747.	7810.	64455.
31	15141.	18429.	16802.	11072.	6010.	3798.	3798.
32	2909.	4488.	6005.	5734.	3862.	1574.	39360.
33	8554.	5359.	3753.	2804.	2189.	1758.	50000.
34	0.	0.	0.	0.	0.	0.	0.
35	8554.	5359.	3753.	2804.	2189.	1758.	50000.
36	330.	330.	330.	330.	330.	330.	3960.
37	163.	97.	169.	350.	180.	48.	2486.
38	23.	98.	138.	147.	169.	110.	728.
39	9450.	8469.	7795.	6529.	5369.	3723.	71509.
40	5670.	5081.	4677.	3917.	3221.	2233.	42985.
41	0.	-.	-.	-.	-.	-.	0.
42	3780.	3387.	3118.	2611.	2147.	1489.	28603.
43	0.	0.	0.	0.	0.	0.	0.
44	14335.	39566.	7484.	6317.	7764.	3484.	125378.
45	14335.	39566.	7484.	6317.	7764.	3484.	125378.
46	15450.	45209.	13469.	10119.	5750.	3590.	139009.
47	-1114.	-5643.	-5985.	-3802.	2014.	-105.	-13631.

Table E-4.b. Continued.

PRICE RIVER FROM HEINER TO WOODSIDE YEAR 1973

SALT

	VAR	OCT	NOV	DEC	JAN	FEB	MAR
48	SM MG/L	2387.	1855.	1766.	1764.	1782.	1375.
49	SALTIN	42621.	5484.	996.	850.	802.	12231.
50	NAT PU	385.	212.	197.	192.	191.	253.
51	AGR PU	25762.	16674.	13435.	11422.	14112.	17421.
52	RES REL	0.	0.	0.	0.	0.	0.
53	RES STP	0.	0.	0.	0.	0.	0.
54	URB SUR	594.	168.	0.	0.	0.	614.
55	PUMP IN	0.	0.	0.	0.	0.	0.
56	RIVER GW	0.	0.	0.	0.	0.	0.
57	SALT AVL	43371.	5855.	1331.	1147.	1093.	12624.
58	M+I DIV	399.	347.	347.	347.	347.	347.
59	M+I RET	688.	598.	598.	598.	598.	598.
60	SALT AVL	43660.	6106.	1581.	1398.	1344.	12875.
61	CNL DIV	4619.	1913.	1201.	1075.	1046.	1700.
62	CNL SEEP	970.	401.	252.	225.	219.	357.
63	CNL GW	1459.	631.	548.	420.	394.	555.
64	SLEP RET	364.	157.	137.	105.	98.	138.
65	SPILL	46.	19.	12.	10.	10.	17.
66	FARM DEL	3603.	1492.	936.	838.	816.	1326.
67	TAILWTR	590.	246.	168.	144.	140.	221.
68	APPLIED	3062.	1268.	796.	712.	694.	1127.
69	SMSTRG	43460.	37944.	33351.	29664.	25670.	23554.
70	PCP RTZN	0.	0.	0.	0.	0.	0.
71	PCP DP	0.	0.	0.	0.	0.	0.
72	DPSALT	9207.	6784.	5389.	4398.	3688.	4243.
73	ROUT DP	15578.	20995.	16177.	14204.	22745.	35403.
74	PPM ARF	1789.	3580.	3357.	3347.	4242.	6132.
75	ARF DIV	0.	0.	0.	0.	0.	0.
76	ARF RTN	15578.	20995.	16177.	14204.	22745.	35403.
77	GW IN	139.	139.	139.	139.	139.	139.
78	URBGW IN	594.	168.	0.	0.	0.	614.
79	GW EFL	29090.	17913.	14068.	11985.	14658.	18493.
80	GW CONC	4568.	4407.	4246.	4106.	4097.	4238.
81	GW OUT	19393.	11942.	9379.	7990.	9772.	12329.
82	CH GWSTR	-29817.	-7125.	-5786.	-4415.	-355.	6686.
83	EXPORT	0.	0.	0.	0.	0.	0.
84	SUR RO	68768.	22371.	14630.	12464.	15106.	29906.
85	COMP OUT	68768.	22371.	14630.	12464.	15106.	29906.
86	GAGE OUT	67124.	15335.	13816.	8358.	9132.	30509.
87	DIFF	1644.	7036.	814.	4106.	5973.	-603.
88	COMP TDS	2181.	3134.	3618.	3679.	3777.	2308.
89	GAGE TDS	2200.	2800.	3399.	2500.	2400.	2100.
90	DIFF	-18.	334.	218.	1179.	1377.	208.

Table E-4.b. Continued.

	APR	MAY	JUN	JUL	AUG	SEP	ANN
48	1045.	941.	1004.	1346.	2001.	3055.	1693.
49	6042.	28295.	16053.	15895.	14113.	7822.	151209.
50	290.	669.	394.	363.	367.	276.	3795.
51	29176.	18735.	9143.	4733.	4220.	3032.	167871.
52	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.
54	163.	97.	169.	350.	180.	48.	2486.
55	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.
57	6504.	30594.	18830.	18425.	16319.	9239.	165417.
58	347.	347.	517.	517.	517.	399.	4786.
59	598.	598.	891.	891.	891.	688.	8241.
60	6835.	30845.	19204.	18798.	16692.	9528.	168871.
61	1625.	10660.	19204.	18798.	14603.	9528.	85977.
62	341.	2238.	4032.	3947.	3066.	2000.	18055.
63	1001.	6519.	9528.	8567.	7348.	4559.	41634.
64	250.	1629.	2382.	2166.	1837.	1139.	10408.
65	16.	106.	192.	187.	146.	95.	859.
66	1267.	8315.	14979.	14663.	11390.	7431.	67062.
67	250.	1646.	2764.	2641.	2102.	1345.	12263.
68	1077.	7068.	12732.	12463.	9682.	6317.	57002.
69	28661.	22299.	25807.	25213.	21244.	19483.	19483.
70	0.	0.	0.	0.	0.	0.	0.
71	0.	0.	0.	0.	0.	371.	371.
72	3970.	5430.	9223.	13058.	13651.	8078.	87124.
73	19387.	22881.	15407.	11661.	9285.	7682.	211410.
74	1667.	3141.	3020.	3060.	3120.	3213.	3306.
75	0.	0.	0.	0.	0.	0.	0.
76	19387.	22881.	15407.	11661.	9285.	7682.	211410.
77	139.	139.	139.	139.	139.	139.	1668.
78	163.	97.	169.	350.	180.	48.	2486.
79	30032.	25762.	22635.	18162.	14364.	9691.	226859.
80	3897.	3730.	3561.	3411.	3280.	3192.	3894.
81	20021.	17174.	15090.	12108.	9576.	6460.	151239.
82	-28567.	-12503.	-11685.	-8655.	-6192.	-2926.	-111343.
83	0.	0.	0.	0.	0.	0.	0.
84	35510.	47700.	25591.	20991.	18702.	11131.	322877.
85	35510.	47700.	25591.	20991.	18702.	11131.	322877.
86	33596.	49154.	27459.	28882.	15629.	11221.	310221.
87	1914.	-1454.	-1868.	-7891.	3073.	-89.	12655.
88	1822.	807.	2515.	2445.	1772.	2358.	1094.
89	1600.	800.	1500.	2100.	2000.	2300.	1042.
90	222.	87.	1015.	345.	-227.	50.	252.

Table E-4.b. Continued.

PRICE RIVER FROM HEINER TO WOODSIDE — YEAR 1974

WATER

VAR	OCT	NOV	DEC	JAN	FEB	MAR
1 PHR TEMP	51.694	37.589	29.119	19.109	24.219	41.054
2 PRECIP	.319	.354	.465	.744	.082	.069
3 SNOW MLT	.000	.000	.219	.000	.000	1.057
4 SNOW STR	.000	.000	.246	.990	1.072	.015
5 PHR ET	2.446	.649	.622	.359	.467	1.397
6 CROP PET	1.448	.477	.232	.128	.181	.589
7 CROP AET	1.317	.477	.232	.128	.181	.589
8 SM STR	1.984	2.419	2.613	2.635	2.581	3.309
9 RIVER IN	2880.	1500.	1700.	1030.	940.	1760.
10 TRIB IN	1500.	700.	300.	200.	200.	500.
11 UNG IN	651.	39.	238.	0.	0.	2010.
12 PHR RPSN	47.	52.	32.	0.	0.	166.
13 URB SRF	53.	59.	35.	0.	0.	187.
14 PUMP IN	0.	0.	0.	0.	0.	0.
15 RIVER GW	0.	0.	0.	0.	0.	0.
16 PHP SUR	250.	58.	47.	42.	55.	31.
17 WTR AVL	5050.	2339.	2273.	1221.	1115.	4503.
18 M+I DIV	775.	670.	670.	670.	670.	670.
19 M+I PET	697.	603.	603.	603.	603.	603.
20 WTR AVL	4972.	2272.	2206.	1154.	1048.	4436.
21 CNL DIV	4972.	2272.	1066.	806.	728.	1885.
22 CNL SEEP	1044.	477.	223.	169.	152.	395.
23 CNL GW	856.	399.	186.	137.	122.	309.
24 SEEP RTN	216.	99.	46.	34.	30.	77.
25 SPILL	49.	22.	10.	8.	7.	18.
26 FARM DEL	3876.	1772.	831.	628.	567.	1470.
27 TAIL WTR	581.	265.	124.	94.	85.	220.
28 TAL EVP	0.	0.	0.	0.	0.	0.
29 TOT SPL	4004.	2291.	1191.	534.	482.	3742.
30 CROP AET	2914.	1055.	513.	284.	400.	1304.
31 SM STR	4389.	5351.	5782.	5830.	5711.	7319.
32 DP	498.	274.	245.	201.	200.	828.
33 ROUT DP	2465.	2745.	3847.	5211.	5541.	4480.
34 REDIV PF	0.	0.	0.	0.	0.	0.
35 RDP NDIV	2465.	2745.	3847.	5211.	5541.	4480.
36 GW IN	330.	330.	330.	330.	330.	330.
37 URBGW IN	53.	59.	36.	0.	3.	187.
38 PHR GW	62.	14.	11.	10.	13.	8.
39 ROUT GW	3651.	3519.	4388.	5667.	5980.	5299.
40 EFFL GW	2191.	2111.	2633.	3400.	3588.	3179.
41 CH GWSTR	-.	-.	.	.	.	-.
42 GW OUT	1460.	1407.	1755.	2267.	2392.	2119.
43 CHNL EXP	0.	0.	3.	0.	0.	0.
44 SUR RNOF	2822.	2400.	3909.	3852.	4001.	5978.
45 COMP OUT	2822.	2400.	3909.	3852.	4001.	5978.
46 GAGE OUT	4300.	3220.	3800.	3730.	3370.	3730.
47 DIFF	-1477.	-819.	109.	122.	631.	2248.

Table E-4.b. Continued.

	APR	MAY	JUN	JUL	AUG	SEP	ANN
1	43.889	60.374	68.669	74.199	72.659	65.169	48.979
2	.383	.000	.012	1.282	.218	.221	4.154
3	.015	.000	.000	.000	.000	.000	1.292
4	.000	.000	.000	.000	.000	.000	.000
5	1.877	4.788	6.555	7.967	7.083	4.773	39.189
6	.858	2.673	6.502	8.700	6.985	4.415	33.113
7	.858	2.673	6.502	8.111	4.328	2.054	27.455
8	4.558	7.238	4.376	.532	.000	.000	2.687
9	4980.	17400.	13000.	10100.	11000.	3740.	70029.
10	2520.	7000.	5750.	4750.	4000.	2400.	29800.
11	576.	840.	630.	351.	348.	285.	5968.
12	58.	.	1.	189.	32.	32.	612.
13	66.	.	2.	213.	36.	36.	692.
14	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.
16	174.	565.	772.	788.	810.	537.	4134.
17	8283.	25664.	19421.	15259.	15145.	6193.	106482.
18	670.	670.	1000.	1000.	1000.	775.	9240.
19	603.	633.	900.	900.	900.	697.	8316.
20	8216.	25597.	19321.	15169.	15045.	6115.	105558.
21	8216.	24127.	19174.	15169.	13545.	6115.	98080.
22	1725.	5066.	4026.	3185.	2844.	1284.	20596.
23	1342.	3956.	3247.	2573.	2286.	1072.	16500.
24	335.	989.	811.	643.	571.	268.	4125.
25	82.	241.	191.	151.	135.	61.	980.
26	6408.	18819.	14956.	11832.	10565.	4770.	76503.
27	961.	2822.	2243.	1774.	1584.	715.	11475.
28	0.	0.	0.	0.	0.	0.	0.
29	6329.	15997.	12741.	12894.	9464.	4545.	74218.
30	1897.	5913.	14384.	17942.	9576.	4545.	60734.
31	10083.	16012.	9680.	1178.	0.	0.	0.
32	1668.	4154.	4688.	3453.	1066.	0.	17282.
33	2643.	1287.	647.	394.	272.	227.	29764.
34	0.	0.	0.	0.	0.	0.	0.
35	2643.	1287.	647.	394.	272.	227.	29764.
36	330.	330.	330.	330.	330.	330.	3960.
37	66.	.	2.	213.	36.	36.	692.
38	43.	141.	193.	197.	202.	134.	1033.
39	4338.	5433.	4034.	3314.	2722.	1532.	49883.
40	2603.	3259.	2420.	1988.	1633.	919.	29930.
41	-.	.	-.	-.	-.	-.	-.
42	1735.	2173.	1613.	1325.	1289.	612.	19953.
43	0.	0.	0.	0.	0.	0.	0.
44	3646.	7793.	5002.	3914.	4953.	1696.	49864.
45	3646.	7793.	5002.	3914.	4853.	1696.	49864.
46	3030.	4600.	3620.	3600.	1160.	960.	39119.
47	616.	3193.	1382.	314.	3693.	736.	10744.

Table E-4.b. Continued.

PRICE RIVER FROM HEINER TO WOODSIDE YEAR 1974
SALT

	VAR	OCT	NOV	DEC	JAN	FEB	MAR
48	SM MG/L	3576.	3115.	2759.	2639.	2655.	2337.
49	SALTIN	3618.	1807.	1804.	1044.	969.	6696.
50	NAT PU	229.	203.	203.	193.	192.	225.
51	AGR PU	6018.	6868.	9609.	12263.	13050.	10287.
52	RES REL	0.	0.	0.	0.	0.	0.
53	RES STR	0.	0.	0.	0.	0.	0.
54	UPF SUR	53.	59.	36.	0.	0.	187.
55	PUMP IN	0.	0.	0.	0.	0.	0.
56	RIVER GW	0.	0.	0.	0.	0.	0.
57	SALT AVL	4427.	2295.	2140.	1344.	1259.	7186.
58	M+I DIV	424.	366.	366.	366.	366.	366.
59	M+I RET	730.	631.	631.	631.	631.	631.
60	SALT AVL	4733.	2560.	2405.	1609.	1524.	7451.
61	CNL DIV	4733.	2560.	1161.	1123.	1058.	3165.
62	CNL SEEP	994.	537.	244.	235.	222.	664.
63	CNL GW	2314.	1136.	525.	427.	389.	1053.
64	SEEP RET	578.	284.	131.	106.	97.	263.
65	SPILL	47.	25.	11.	11.	10.	31.
66	FARM DEL	3692.	1997.	906.	876.	825.	2469.
67	TAILWTR	670.	352.	160.	150.	140.	414.
68	APPLIED	3138.	1697.	779.	744.	701.	2099.
69	SMSTRG	20313.	20937.	20819.	20843.	20813.	20582.
70	PCP RTZN	0.	0.	0.	0.	0.	0.
71	PCP DP	0.	0.	0.	0.	0.	0.
72	DPSALT	2308.	1073.	888.	720.	731.	2330.
73	ROUT DP	8078.	8609.	11169.	16564.	21676.	23298.
74	PPM AFF	2411.	2306.	2136.	2338.	2877.	3826.
75	ARF DIV	0.	0.	0.	0.	0.	0.
76	ARF RTN	8076.	8609.	11169.	16564.	21676.	23298.
77	GW IN	139.	139.	139.	139.	139.	139.
78	UPBGW IN	53.	59.	36.	0.	0.	187.
79	GW EFL	9149.	8501.	10201.	12853.	13594.	12477.
80	GW CONC	3072.	2962.	2850.	2781.	2787.	2887.
81	GW OUT	6299.	5667.	6801.	8568.	9063.	8318.
82	CH GWSTR	-3867.	-3429.	-4336.	-3494.	343.	4678.
83	EXPORT	0.	0.	0.	0.	0.	0.
84	SUR RO	9866.	8880.	11617.	13500.	14212.	17209.
85	COMP OUT	9866.	8880.	11617.	13500.	14212.	17209.
86	GAGE OUT	14609.	11378.	13427.	12673.	10534.	12166.
87	DIFF	-4743.	-2498.	-1809.	827.	3678.	5042.
88	COMP TDS	2572.	2722.	2186.	2578.	2613.	2120.
89	GAGE TDS	2500.	2600.	2600.	2500.	2300.	2400.
90	DIFF	72.	122.	-413.	78.	313.	-279.

Table E-4.b. Continued.

	APR	MAY	JUN	JUL	AUG	SEP	ANN
48	1799.	1429.	1601.	2473.	5805.	0.	2516.
49	6168.	19429.	14834.	11656.	11728.	5383.	85142.
50	261.	428.	367.	327.	327.	240.	3202.
51	5403.	-2092.	-2801.	-2161.	-2550.	-1136.	52757.
52	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.
54	66.	.	2.	213.	36.	36.	692.
55	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.
57	7316.	22436.	17344.	13689.	13569.	6378.	99389.
58	366.	366.	547.	547.	547.	424.	5060.
59	631.	631.	942.	942.	942.	730.	8712.
60	7581.	22701.	17739.	14284.	13965.	6685.	103041.
61	7581.	21398.	17604.	14084.	12572.	6685.	93730.
62	1592.	4493.	3697.	2957.	2640.	1403.	19683.
63	3546.	10314.	8567.	6815.	6054.	3016.	44162.
64	886.	2578.	2141.	1703.	1513.	754.	11040.
65	75.	213.	176.	140.	125.	66.	937.
66	5913.	16690.	13731.	10985.	9806.	5214.	73110.
67	1079.	3068.	2588.	2002.	1788.	925.	13261.
68	5026.	14187.	11672.	9337.	8335.	4432.	62143.
69	21973.	28711.	27205.	9298.	.	4432.	4432.
70	0.	0.	0.	0.	0.	0.	0.
71	0.	0.	0.	8473.	11835.	0.	20308.
72	3635.	7448.	13178.	18771.	5799.	0.	56886.
73	18269.	8634.	4246.	2753.	2125.	1911.	127336.
74	5084.	4933.	4827.	5140.	5742.	6193.	3985.
75	0.	0.	0.	0.	0.	0.	0.
76	18269.	8634.	4246.	2753.	2125.	1911.	127336.
77	139.	139.	139.	139.	139.	139.	1668.
78	66.	.	2.	213.	36.	36.	692.
79	10677.	13179.	9581.	7679.	6200.	3496.	117592.
80	3018.	2974.	2912.	2841.	2792.	2798.	2889.
81	7118.	8786.	6387.	5119.	4133.	2330.	78395.
82	5021.	-2081.	-2216.	-2081.	-1181.	73.	-12572.
83	0.	0.	0.	0.	0.	0.	0.
84	11832.	17764.	12400.	9823.	9505.	4488.	141102.
85	11832.	17764.	12400.	9823.	9505.	4488.	141102.
86	9759.	11678.	10823.	10763.	4098.	3914.	125327.
87	2773.	5886.	1576.	-940.	5407.	574.	15775.
88	2387.	1677.	1823.	1846.	1441.	1947.	2082.
89	2199.	1900.	2200.	2200.	2600.	3000.	2357.
90	187.	-222.	-376.	-353.	-1158.	-1052.	-275.

Table E-4.b. Continued.

PRICE RIVER FROM HEINER TO WOODSIDE — YEAR 1975

WATER

	VAR	OCT	NOV	DEC	JAN	FEB	MAR
1	FHR TEMP	54.074	37.274	27.054	23.449	28.174	36.224
2	PRECIP	3.578	.465	.402	.798	.684	1.545
3	SNOW MLT	.000	.000	.006	.000	.557	1.236
4	SNOW STR	.000	.000	.395	1.193	1.319	.082
5	PHR ET	2.740	.828	.578	.440	.544	.973
6	CROP PET	1.622	.465	.215	.158	.210	.410
7	CROP AET	1.622	.465	.215	.158	.210	.410
8	SM STR	2.417	2.704	2.673	2.649	3.065	5.171
9	RIVER IN	1250.	1140.	950.	680.	850.	2030.
10	TRIB IN	850.	450.	300.	200.	250.	500.
11	UNG IN	4250.	0.	0.	0.	915.	2548.
12	PHR RPSH	527.	68.	1.	0.	82.	410.
13	URB SRF	596.	77.	1.	0.	92.	463.
14	PUMP IN	0.	0.	0.	0.	0.	0.
15	RIVER GW	0.	0.	0.	0.	0.	0.
16	PHR SUR	0.	42.	67.	52.	0.	0.
17	WTR AVL	7198.	1694.	1226.	861.	2150.	5882.
18	M+I DIV	850.	740.	740.	740.	740.	740.
19	M+I RET	765.	666.	666.	666.	666.	666.
20	WTR AVL	7113.	1620.	1152.	787.	2076.	5808.
21	CNL DIV	2912.	1599.	1001.	787.	962.	1768.
22	CNL SEEP	611.	335.	210.	165.	202.	371.
23	CNL GW	510.	277.	172.	133.	160.	292.
24	SEEP RTN	127.	69.	43.	33.	40.	73.
25	SPILL	29.	15.	10.	7.	9.	17.
26	FARM DEL	2271.	1247.	780.	614.	750.	1379.
27	TAIL WTR	340.	167.	117.	92.	112.	206.
28	TAL EVP	0.	0.	0.	0.	0.	0.
29	TOT SPL	9846.	2089.	678.	522.	1871.	7326.
30	CROP AET	3590.	1029.	477.	349.	466.	908.
31	SM STR	5348.	5983.	5913.	5860.	6781.	11439.
32	DP	907.	425.	270.	225.	484.	1759.
33	RCUT DP	607.	1277.	3096.	4103.	3692.	2832.
34	REDIV DP	0.	0.	0.	0.	0.	0.
35	RDP NDIV	607.	1277.	3096.	4103.	3692.	2832.
36	GW IN	330.	330.	330.	330.	330.	330.
37	URBGW IN	596.	77.	1.	0.	92.	463.
38	PHR GW	0.	10.	16.	13.	0.	0.
39	ROUT GW	2043.	1952.	3582.	4553.	4275.	3118.
40	EFFL GW	1226.	1171.	2149.	2732.	2565.	1871.
41	CH GWSTR	.	-.	.	.	-.	-.
42	GW OUT	817.	780.	1432.	1821.	1710.	1247.
43	CHNL EXP	0.	0.	0.	0.	0.	0.
44	SUR RNOF	5797.	1395.	2428.	2832.	3802.	6136.
45	COMP OUT	5797.	1395.	2428.	2832.	3802.	6136.
46	GAGE OUT	2950.	2050.	1290.	1320.	1640.	2900.
47	DIFF	2847.	-654.	1138.	1512.	2162.	3236.

Table E-4.b. Continued.

	APR	MAY	JUN	JUL	AUG	SEP	ANN
1	40.214	51.589	60.759	73.569	70.909	63.874	47.264
2	.376	1.136	1.336	1.649	.281	.712	12.967
3	.081	.001	.000	.000	.000	.000	1.884
4	.001	.000	.000	.000	.000	.000	.000
5	1.474	3.240	4.892	7.811	6.690	4.549	34.765
6	.673	1.808	4.852	8.530	6.522	4.208	29.680
7	.673	1.808	4.852	8.530	6.522	4.136	29.608
8	5.163	7.883	6.046	5.111	2.929	2.170	4.165
9	5060.	10300.	27900.	17300.	13100.	7800.	88359.
10	1000.	5400.	6300.	6750.	6000.	4000.	32000.
11	210.	1116.	1323.	1063.	324.	246.	11997.
12	67.	167.	197.	243.	41.	105.	1912.
13	76.	189.	222.	274.	46.	118.	2161.
14	0.	0.	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.	0.	0.
16	119.	248.	419.	727.	756.	452.	2886.
17	6373.	17466.	36203.	25605.	19535.	12233.	136431.
18	740.	740.	1100.	1100.	1100.	850.	10180.
19	666.	666.	990.	990.	990.	755.	9162.
20	6299.	17392.	36093.	25495.	19425.	12148.	135413.
21	3562.	17392.	21033.	22541.	19425.	12148.	105134.
22	748.	3652.	4417.	4733.	4079.	2551.	22078.
23	587.	2838.	3508.	3777.	3281.	2085.	17625.
24	146.	709.	877.	944.	820.	521.	4406.
25	35.	173.	210.	225.	194.	121.	1051.
26	2778.	13566.	16406.	17582.	15151.	9476.	82004.
27	416.	2034.	2460.	2637.	2272.	1421.	12300.
28	0.	0.	0.	0.	0.	0.	0.
29	3375.	14049.	16901.	18594.	13502.	9630.	98389.
30	1490.	4001.	10734.	18869.	14428.	9149.	65496.
31	11423.	17438.	17798.	11307.	6480.	4801.	4801.
32	1901.	4032.	5806.	6216.	3900.	2160.	28091.
33	747.	848.	581.	384.	284.	410.	18067.
34	0.	0.	0.	0.	0.	0.	0.
35	747.	848.	581.	384.	284.	410.	18067.
36	330.	330.	330.	330.	330.	330.	3960.
37	76.	189.	222.	274.	46.	118.	2161.
38	29.	62.	104.	181.	189.	113.	721.
39	1711.	4144.	4538.	4585.	3753.	2831.	41091.
40	1027.	2486.	2722.	2751.	2252.	1699.	24655.
41	-.	0.	.	.	-.	-.	.
42	684.	1657.	1815.	1834.	1501.	1132.	16436.
43	0.	0.	0.	0.	0.	0.	0.
44	4216.	4695.	20453.	8567.	4719.	3241.	68286.
45	4216.	4695.	20453.	8567.	4719.	3241.	68286.
46	3760.	5450.	14769.	7300.	2410.	3380.	49219.
47	456.	-754.	5683.	1267.	2309.	-138.	19066.

Table E-4.b. Continued.

PRICE RIVER FROM HEINER TO WOODSIDE — YEAR 1975
SALT

	VAR	OCT	NOV	DEC	JAN	FEB	MAR
46	SM MG/L	1557.	944.	980.	1055.	1040.	754.
49	SALTIN	12301.	1326.	930.	698.	3046.	8889.
50	NAT PU	252.	197.	193.	189.	282.	239.
51	AGR PU	672.	3166.	7222.	9635.	9616.	6323.
52	RES REL	0.	0.	0.	0.	0.	0.
53	RES STF	0.	0.	0.	0.	0.	0.
54	URB SUR	596.	77.	1.	0.	92.	463.
55	PUMP IN	0.	0.	0.	0.	0.	0.
56	RIVER GW	0.	0.	0.	0.	0.	0.
57	SALT AVL	13012.	1730.	1256.	1008.	3390.	8566.
58	M+I DIV	465.	405.	405.	405.	405.	405.
59	M+I RET	801.	697.	697.	697.	697.	697.
60	SALT AVL	13348.	2022.	1548.	1293.	3682.	8859.
61	CNL DIV	5464.	1996.	1344.	1293.	1706.	2696.
62	CNL SEEP	1147.	419.	282.	271.	358.	566.
63	CNL GW	1834.	823.	527.	449.	561.	948.
64	SEEP RET	458.	205.	131.	112.	140.	237.
65	SPILL	54.	19.	13.	12.	17.	26.
66	FARM DEL	4262.	1557.	1049.	1008.	1330.	2103.
67	TAILWTR	707.	271.	180.	169.	222.	356.
68	APPLIED	3623.	1323.	891.	857.	1131.	1787.
69	SMSTRG	6886.	7665.	8182.	8705.	9180.	9505.
70	PCP RTZN	0.	0.	0.	0.	0.	0.
71	PCP DP	0.	0.	0.	0.	0.	0.
72	DPSALT	1166.	545.	374.	334.	656.	1462.
73	POUT DP	3362.	5445.	10939.	18429.	26353.	14841.
74	FRM ARF	4472.	3135.	2599.	3304.	5251.	5372.
75	ARF DIV	0.	0.	0.	0.	0.	0.
76	ARF RTN	3362.	5445.	10939.	18429.	26353.	14841.
77	GW IN	139.	139.	139.	139.	139.	139.
78	URBGW IN	596.	77.	1.	0.	92.	463.
79	GW FFL	4580.	4373.	7948.	10341.	10649.	8106.
80	GW CONC	2748.	2747.	2720.	2784.	3054.	3187.
81	GW OUT	3053.	2915.	5298.	6894.	7099.	5404.
82	CH GWSTR	-904.	-8.	-844.	2578.	10193.	3679.
83	EXPORT	0.	0.	0.	0.	0.	0.
84	SUR RO	13226.	4690.	8346.	10523.	12865.	14652.
85	COMP OUT	13226.	4690.	8346.	10523.	12865.	14652.
86	GAGE OUT	10023.	7522.	6136.	4484.	5349.	9064.
87	DIFF	3203.	-2831.	2210.	6039.	7515.	5587.
88	COMP TDS	1678.	2473.	2529.	2734.	2489.	1757.
89	GAGE TDS	2500.	2700.	3500.	2500.	2400.	2300.
90	DIFF	-821.	-226.	-972.	234.	89.	-542.

Table E-4.b. Continued.

	APR	MAY	JUN	JUL	AUG	SEP	ANN
48	641.	691.	747.	999.	1658.	2489.	1130.
49	6108.	12836.	19264.	18183.	13719.	8893.	105401.
50	243.	349.	534.	428.	368.	298.	3499.
51	1525.	-1045.	1864.	-3213.	-3562.	-1647.	30558.
52	0.	0.	0.	0.	0.	0.	0.
53	0.	0.	0.	0.	0.	0.	0.
54	76.	189.	222.	274.	46.	118.	2161.
55	0.	0.	0.	0.	0.	0.	0.
56	0.	0.	0.	0.	0.	0.	0.
57	6770.	15032.	21850.	21331.	16203.	10556.	120401.
58	405.	405.	602.	602.	602.	465.	5575.
59	697.	697.	1037.	1037.	1037.	801.	9599.
60	7062.	15324.	22284.	21466.	16637.	10892.	124425.
61	3993.	15324.	12986.	18979.	16637.	10892.	93317.
62	838.	3218.	2727.	3985.	3493.	2287.	19596.
63	1669.	7383.	8201.	9676.	8455.	5456.	45986.
64	417.	1845.	2050.	2419.	2113.	1364.	11496.
65	39.	153.	129.	189.	166.	108.	933.
66	3115.	11953.	10129.	14803.	12977.	8496.	72787.
67	550.	2199.	2011.	2748.	2401.	1558.	13378.
68	2647.	10160.	8610.	12583.	11030.	7221.	61869.
69	10419.	16714.	19095.	20440.	19847.	18530.	18530.
70	0.	0.	0.	0.	0.	0.	0.
71	0.	0.	0.	0.	0.	0.	0.
72	1734.	3865.	6229.	11238.	11823.	8338.	47771.
73	1864.	3109.	2360.	1853.	1591.	1915.	92065.
74	1835.	2695.	2986.	3542.	4121.	3430.	3529.
75	0.	0.	0.	0.	0.	0.	0.
76	1864.	3109.	2360.	1853.	1591.	1915.	92065.
77	139.	139.	139.	139.	139.	139.	1668.
78	76.	189.	222.	274.	46.	118.	2161.
79	4220.	9786.	10224.	9973.	7958.	5877.	94039.
80	3023.	2895.	2763.	2667.	2600.	2545.	2811.
81	2813.	6524.	6816.	6648.	5305.	3918.	62693.
82	-2487.	-4693.	-5321.	-3881.	-2235.	-1369.	-5294.
83	0.	0.	0.	0.	0.	0.	0.
84	7879.	12139.	21664.	15398.	10526.	7545.	139458.
85	7879.	12139.	21664.	15398.	10526.	7545.	139458.
86	13797.	17776.	18066.	29763.	5240.	9187.	136411.
87	-5917.	-5636.	3598.	-14365.	5285.	-1641.	3046.
88	1374.	1902.	779.	1322.	1641.	1712.	1502.
89	2700.	2400.	900.	2999.	1600.	2000.	2039.
90	-1325.	-497.	-120.	-1677.	41.	-287.	-536.
	OBJ =	1595.61279	OAJ =	31477.74			
	193.16	16178.80	1595.61	31477.74		14.87	-558.89